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THESIS

DEVELOPING A UNITED STATES MARINE CORPS ORGANIZATIONAL AND INTERMEDIATE LEVEL MAINTENANCE PERFORMANCE COST MODEL

by

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December 2009

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13. ABSTRACT (maximum 200 words)

Headquarters Marine Corps (HQMC) Installations and Logistics (I&L) is concerned over the expenditures on organizational and intermediate (O&I)-level maintenance repairables and consumables, and their effects on future budget requests. Additionally, determining the effect of O&I cost-drivers, such as inventory, operating tempo (OPTEMPO), equipment age, procurement costs, etc., has not been thoroughly examined. Developing a cost-estimating relationship with maintenance costs, these cost-drivers variables can help explain the factors that affect costs and why they vary. Prior studies have analyzed maintenance costs and have suggested various prediction methods. The Marine Corps has yet to implement a quantitative forecasting method to predict maintenance costs. As such, this thesis analyzes and suggests methods to predict future budgets at the Marine Force (MARFOR) level using the Operating and Support (O&S) Cost Estimating Guide dated October 2007 as a reference for developing cost-estimating relationships.

This thesis focuses on the following three MARFORs: (1) Marine Forces Pacific, (2) Marine Forces Command, and (3) Marine Forces Reserve. This thesis creates a performance-pricing model for the USMC planners to use as an analytical tool to support sustainment budgetary requirements in the Planning, Programming, Budgeting, and Execution (PPBE) process**.** This thesis continues the work of LCDR Patrick Kelly.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFCAA	Air Force Cost Analysis Agency
AFTOC	Air Force Total Ownership Cost
APC	Armored Personnel Carrier
AR	Autoregressive
ARIMA	Autoregressive Integrated Moving Average
ATLASS	Asset Tracking Logistics and Supply System
CAIG	Cost Analysis Improvement Group
CBO	Congressional Budget Office
CBREPRI	CB Richard Ellis Prime Rent Index
CBRN	Chemical, Biological, Radiological, Nuclear
CEAC	Cost and Economic Analysis Center
CER	Cost-Estimating-Relationship
DoD	Department of Defense
ERO	Equipment Repair Order
EROSL	Equipment Repair Order Shopping List
FY	Fiscal Year
GAO	General Accounting Office
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HQMC	Headquarters United States Marine Corps
I&L	Installation and Logistics
IMA	Intermediate Maintenance Activity
IOC	Initial Operational Capability
JLL	Jones Lang LaSalle
LFADS	Landing Force Asset Distribution System
LIS	Logistics Integrated Support
LN	Natural Log
LVS	Logistics Vehicle System
MARCORLOGCOM	Marine Corps Logistics Command
MARCORSYSCOM	Marine Corps Systems Command
MARES	Marine Corps Automated Readiness Evaluation System
MARFOR	Marine Force
MARFORCOM	Marine Forces Command

MARFORPAC	Marine Forces Pacific
MARFORRES	Marine Forces Reserve
MARFORSOC	Marine Forces Special Operations Command
MCBUL	Marine Corps Bulletin
MCCSSS	Marine Corps Combat Service Support School
MCO	Marine Corps Order
MDBM	Mean Days between Maintenance
MEE	Mission Essential Equipment
MEF	Marine Expeditionary Force
MERIT	Marine Corps Equipment Readiness Information Tool
MIMMS	Marine Corps Integrated Maintenance Management System
MIPR	Military Interdepartmental Purchase Request
MLG	Marine Corps Logistics Unit
MOSIS	Marine Operating and Support Information System
MRIPT	Material Readiness Integrated Product Team
MRP	Materials Return Program
NCCA	Naval Center for Cost Analysis
O&I	Organizational and Intermediate
O&M	Operations and Maintenance
O&S	Operating and Support
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OLS	Ordinary Least Squares
OPTEMPO	Operating Tempo
OSD	Office of the Secretary of Defense
OSMIS	Operating and Support Management Information System
P&R	Programs and Resources
PC SASSY	Personal Computer Supported Activities Supply System
PEB	Program Evaluation Board
PEI	Principle End Item
PM	Program Manager
PPBE	Planning, Programming, Budgeting, and Execution
RIP	Repairable Issue Point
SABRS	Standard Accounting, Budgeting, and Reporting System
SASSY	Supported Activities Supply System
SECREP	Secondary Repairable
SMU	SASSY Management Unit
SOE	System Operational Effectiveness

TAMCN	Table of Authorized Material Control Number
TFSMS	Total Force Structure Management System
TOC	Total Ownership Cost
TSC	Total Support Cost
USMC	United States Marine Corps
VAMOSC	Visibility and Management of Operating and Support Costs

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I. INTRODUCTION

A. RESEARCH QUESTIONS

1. Primary Question

- What parametric cost estimating models (e.g., ordinary least squares, autoregressive integrative moving average, etc.) can explain and predict a Marine Force's level of spending for organizational and intermediate level part charges?

2. Secondary Questions

- How much do the Marine Forces annually spend on organizational and intermediate part charges for Marine Corps Bulletin 3000 equipment?
- Can changes in operational tempo and equipment reliability be used to explain budget changes?
- How valid are the data from Visibility and Management of Operating and Support Costs and Marine Corps Logistics Command?

B. EXAMINING ORGANIZATIONAL AND INTERMEDIATE PART COSTS IN THE MARINE CORPS

Headquarters Marine Corps (HQMC) is concerned over the expenditures on organizational and intermediate (O&I)-level consumables and secondary repairables (SECREPs), and their effects on future budget requests. Additionally, determining the effect of O&I cost-drivers, such as inventory, operating tempo (OPTEMPO), equipment age, procurement costs, etc., has not yet been examined. Developing a relationship between cost and these variables helps to understand the factors that affect costs and why they vary. Although prior studies have analyzed spare part costs and suggested prediction methods, the Marine Corps has yet to implement quantitative forecasting measures to predict maintenance costs (Cucinotta, 1997; Klein, 2005; Klein, 2009). As such, this thesis analyzes and suggests methods to predict future expenditures on consumables and SECREPs at the Marine Force (MARFOR) level using the Operating and Support (O&S) Cost Estimating Guide dtd October 2007 as a reference for developing cost-estimating

relationships. This thesis focuses on the following three MARFORs: (1) Marine Forces Pacific (MARFORPAC), (2) Marine Forces Command (MARFORCOM) and (3) Marine Forces Reserve (MARFORRES). Marine Corps Logistics Command (MARCORLOGCOM) and Marine Corps Systems Command (MARCORSYSCOM) provided the part charge data for this thesis. This thesis focuses strictly on the Marine Corps Bulletin (MCBUL) 3000 Table of Authorized Material Control Number (TAMCN)[1] weapon systems.

The Marine Corps Installation and Logistics (I&L) Command initiated this thesis due to growing concerns that the Marine Corps has not found accurate methods to predict the cost of O&I level consumables and SECREPs. Although analysts have studied maintenance cost drivers, gathering accurate, complete data has been a major impediment. With future Department of Defense (DoD) budgets on the decline and the wars in both Iraq and Afghanistan potentially winding down, finding ways to predict these costs accurately is imperative. The most recent study on maintenance cost estimation techniques discussed the growing number of new weapon systems in the Marine Corps' inventory to support Commander's requirements for Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). As such, Marine Corps Systems Command (MARCORSYSCOM) personnel are concerned with the growing inventory's cost of consumables and SECREPs and the resulting budgetary implications (Klein, 2009).

C. RESEARCH OBJECTIVES

This thesis creates a performance-cost model for the USMC planners to use as an analytical tool to support sustainment budgetary requirements in the PPBE process. This thesis focuses on O&I funding requirements by MARFOR. Additionally, this thesis places special emphasis on the initial models that LCDR Patrick Kelly developed, entitled "United States Marine Corps Performance Pricing Model" (2009). This thesis

[1] A TAMCN is a supply-unique description code given to a Principal End Item (PEI) consisting of (1) Commodity Designator, and (2) Item Number.

also refines and amplifies LCDR Kelly's models by examining cost relationships and evaluating their explanatory and predictive power. The remainder of the introduction discusses the limitations and scope of this thesis.

D. RESEARCH LIMITATIONS

The MCBUL 3000 changes annually and has changed substantially since OIF and OEF, incorporating new equipment into the Marine Corps inventory. Therefore, historical data may be minimal to non-existent for some TAMCNs. A similar problem of insufficient data exists for MARFORSOC as well, leading this study to exclude it from analysis. For example, in 2010, MARFORSOC will have four years worth of historical data, which should provide a solid indicator as to what drives O&I level part charges.

Additionally, by employing data incorporated in the USMC MERIT database, this study does not capture payments to maintenance contractors, such as Raytheon and Oshkosh, for repairs. Instead, this study captures the procurement cost of the SECREP being repaired by the contractor. Consequently, this study's forecasting model systematically overestimates actual part cost expenditures. This study also does not capture the credits and reverse credits that the sources of supply fund back to the MARFORs. To compsensate for this overestimation, one can use a cost-factor technique to account for actual expenditures on SECREP repair.

One would normally expect OPTEMPO to have a significant effect on the repair cost of consumables and SECREPs. However, there is no consistent method to measure the OPTEMPO for every MCBUL 3000 TAMCN. For example, analysts measure a vehicle's OPTEMPO in miles driven. On the other hand, for the majority of the Alpha (communications) TAMCNs, Bravo (engineering) TAMCNs, Charlie (chemical, biological, radiological, nuclear/general supply) TAMCNs, and some Echo (ordnance) TAMCNs, OPTEMPO is measured in rounds, hours, or days.[2] Consequently, this study

[2] OPTEMPO can be measured by (1) miles driven, (2) hours of operation, (3) days in use, and (4) rounds fired depending on what the PEI is, and if accurate and reliable data tracks this type of information.

does not include OPTEMPO data. Finally, this study does not include costs for some of the new TAMCNs in the MCBUL 3000 (dtd 14 January 09) because the cost data was not available until October 2009, after this study's data analysis had begun.

E. RESEARCH SCOPE

This thesis focuses on three cost elements using MARCORLOGCOM and MARCORSYSCOM data. These cost elements are Organizational Level Consumables, Intermediate Level Consumables, and Intermediate Level Repair Parts. The *Operating and Support Cost Estimating Guide* defines organizational and intermediate maintenance consumables and repairables as follows.

> Organizational Maintenance—The cost of materials and other costs used to maintain a primary system, training devices, simulators, and support equipment.
>
> - Organization-Level Consumables—This includes the cost of material consumed in the maintenance and support of a primary system and its associated support and training equipment at the unit level.
> - Organization-Level Repair Parts—This includes the costs of material used to repair primary systems and associated support and training equipment at the unit level.
>
> Intermediate Maintenance—The cost of materials including the support costs expended by intermediate level maintenance organization in support of a primary system, simulators, training devices, and associated support equipment.
>
> - Intermediate Level Consumable Parts—The specified cost of government furnished consumable materials used in maintaining and repairing a primary system, simulator, training devices, and associated support equipment by intermediate-level maintenance activities.

- Intermediate Level Repair Parts—The specified cost of the parts used in maintaining and repairing a primary system, simulator, training devices, and associated support equipment by intermediate-level maintenance activities (2007).[3]

The objective is to develop a model, or models, that support the Marine Corps' forecasting of specified O&I costs. This thesis focuses on developing cost estimating relationships (CERs) for MCBUL 3000 TAMCNs, which are those with significant consumable and SECREP part costs.

[3] The above definitions were taken directly from the OSD Cost Estimating Guide. This study does not include the cost of labor. This study only includes SECREP and consumable part charges, which are referred to as part charges. A part charge is based on the determined administrative prices, including Exchange Price and Standard Price.

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II. BACKGROUND AND LITERATURE REVIEW BACKGROUND

A. HEADQUARTERS MARINE CORPS I&L

The Marine Corps I&L department conducts the Sustainment Program Evaluation Board (PEB) as part of the PPBE process. Accordingly, HQMC must estimate the future funds required to support equipment maintenance worldwide. Since these estimates compete with other United States Marine Corps (USMC) funding needs, analysts must base them on reliable data using defensible methodologies.

In support of I&L's priorities, the department needs to improve the defensibility of its estimates in the current budgetary environment. The results of this effort directly support Marines by providing a basis for justifying maintenance funding at the required levels. Additionally, accurate cost estimates allow comptrollers to apportion funds properly across HQMC requirements.

B. OPERATING AND SUPPORT COSTS

The Congressional Budgeting Office (CBO) conducted a study in 1988 on O&S costs for the DoD. This was a period when the DoD budget grew approximately two percent per year from 1980 to 1988 in real (inflation-adjusted) terms. The DoD became concerned that defense budgets would remain constant or steadily decline in the near term. This would have created adverse consequences for funding programs already in the development or procurement phase. The CBO employed several methods to estimate the amount of O&S funding needed over the course of five years (1988). As a result, the CBO study stimulated interest in finding ways to reduce O&S costs and its effects on readiness.

O&S costs consist of sustainment costs incurred from the initial system deployment through the end of system operations. This includes all costs of operating, maintaining, and supporting a fielded system. Specifically, the costs of personnel

(organic and contractor), equipment, supplies, services associated with operating, modifying, maintaining, supplying, training, and supporting a system in the DoD inventory (DoD, 2007).

In October 2007, the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) published the *Operating and Support Cost Estimating Guide*. The purpose of this guide is twofold: (1) review and explain policies and procedures focused on the preparation, documentation, and presentation of system O&S cost estimates, and (2) identify and define a set of standard categories of O&S Cost Elements. Analysts accomplish most O&S cost estimates using a combination of three estimating approaches.

- Parametric Method—This method uses regression or other statistical methods to develop Cost Estimating Relationships (CER). Two subtypes of this method are the following.
  - Actual Costs method—With this method, actual cost experience or trends are used to project future costs for the same system.
  - Cost Factors—Factors applicable to certain cost elements not related to weapon system characteristics. Often considered simple per capita factors applied to direct system manpower to estimate indirect cost elements.
- Analogy Method—This method is used to estimate a cost based on historical data for one analogous system(s).
- Engineering Estimate—This method uses discrete estimates of labor and material costs for maintenance and other support functions. The system being costed normally is broken down into lover-level components (such as parts or assemblies), each of which is costed separately (2007).

This analysis employs parametric methods to explain and predict the relevant costs.

C. MCBUL 3000

The MCBUL 3000 is a listing of principal end items (PEIs) and Mission Essential Equipment (MEE) established by the Marine Corps to capture ground equipment readiness of all Marine Corps Units (HQMC, 2009). The Marine Corps classifies all MCBUL 3000 TAMCNs as Marine Corps Automated Readiness Evaluation System

(MARES) reportable equipment. This equipment is of the highest importance, which Marine Commanders and staffers continuously monitor to ensure maintenance readiness levels throughout the Marine Corps do not hinder operational readiness.[4] Each calendar year, the Marine Corps updates the MCBUL 3000 with additions and deletions of MARES reportable equipment. As of this writing, the most current MCBUL 3000 contains 228 TAMCNs, 68 of which are MEE items. This is an increase of 112 TAMCN from the year prior. The MCBUL 3000 lists TAMCNs in alphanumeric order, grouping them into the following commodity classes.

- A—Communications/Electronics
- B—Engineering
- C—Chemical, Biological, Radiological, Nuclear(CBRN)/General Supply
- D—Ground Transport
- E—Ordnance (2009)

D. VAMOSC

The VAMOSC program began in the 1970s based on a General Accounting Office (GAO) recommendation, subsequently mandated by Congress, that the DoD should accurately determine weapon system O&S costs (IBM, 2009). Under the guidance of the Office of the Secretary of Defense (OSD) CAIG's Cost Element Structure, DoD 5000.4, OSD authorized each service to develop its own general VAMOSC program. Currently, VAMOSC includes the Navy's VAMOSC system, managed by the Naval Center for Cost Analysis (NCCA); the Marine Corps VAMOSC system, managed by the NCCA, the Air Force VAMOSC system, known as Air Force Total Ownership Cost (AFTOC) and managed by the Air Force Cost Analysis Agency (AFCAA); and the Army's Operating and Support Management Information System (OSMIS), managed by the Cost and Economic Analysis Center (CEAC). According to Cheshire (2001), the purpose of VAMOSC is to provide the following.

[4] Maintenance readiness is only one part of operational readiness, which is the ability to accomplish assigned missions. Personnel training, staffing levels and logistics support are other factors that comprise a unit's operational readiness. Maintenance readiness is the availability of an assigned table of equipment (TE).

- Visibility of O&S costs for use in cost analysis of major defense acquisition programs and force structure alternatives in support of the Planning, Programming and Budgeting System (PPBS) process and satisfies the Congressional requirement that the DoD track and report O&S costs for major acquisition programs.
- To provide visibility of critical maintenance and support costs at the subsystem level in sufficient detail to promote cost-conscious design and configuration management of new and fielded defense programs.
- To provide visibility of O&S costs so they may be managed to reduce and control program life-cycle costs.
- To improve the validity and credibility of O&S cost estimates by establishing a widely accepted database; thereby, reducing the cost and time for collecting these defense program O&S costs for specific applications (2001).

E. MARINE CORPS VAMOSC

In October 2000, the USMC Total Ownership Cost (TOC) Integrated Product Team and NCCA agreed to use VAMOSC as the vehicle for capturing, processing, and reporting O&S (IBM, 2009). Marine Corps VAMOSC focuses on ground combat equipment with supply and maintenance data dating back to fiscal year (FY) 1995 and inventory by location dating back to FY 1998. Navy VAMOSC tracks Marine Corps aviation assets. To date, Marine Corps VAMOSC is improving its capabilities as more usage data becomes available. Table 1 lists the current capabilities that Marine Corps VAMOSC provides to its end users:

Element Description	Fiscal Years Available
Organizational Level Parts Costs	FY95 – FY08
Organizational Level Repairables Parts Costs	FY95 – FY08
Organizational Level Consumables Parts Costs	FY95 – FY08
Organizational Level Labor Costs	FY95 – FY08
Organizational Level Labor Hours	FY97 – FY08
Intermediate Level Parts Costs	FY95 – FY08
Intermediate Level Repairables Parts Costs	FY95 – FY08
Intermediate Level Consumables Parts Costs	FY95 – FY08
Intermediate Level Labor Costs	FY95 – FY08
Intermediate Level Labor Hours	FY97 – FY08
Total Parts Cost	FY95 – FY08
Total Labor Cost	FY95 – FY08
Total Labor Hours	FY97 – FY08
Depot Level Maintenance Cost	FY97 – FY08
Ammunition Cost	FY00 – FY08
Cost per Round	FY00 – FY08
Quantity Fired	FY00 – FY08
Inventory	FY98 – FY08
Average OPTEMPO	FY95 – FY08
Fuel Cost	FY98 – FY08

Table 1. Current USMC VAMOSC Capabilities (From: IBM, 2009)

At the close of the FY, MARFORLOGCOM and MARFORSYCOM provide data that Marine Corps VAMOSC requires to update its database. Most of the data originates from the Asset Tracking Logistics and Supply System (ATLASS), Marine Corps Integrated Maintenance Management System (MIMMS), and Supported Activities Supply System (SASSY). Supply and maintenance personnel within the Marine Corps use these systems to track readiness and inventory, as well as to management the requisition of repair parts, equipment, and materials.

ATLASS is a deployable, microcomputer-based supply system that integrates the functionality of the Landing Force Asset Distribution System (LFADS) and the Personal Computer Support Activities Supply System (PC SASSY) to provide the ability to control, distribute, and replenish equipment and supplies in assigned areas of operation, to receive supply support from and provide supply support to other services (Jackson, 2009).

SASSY is the primary retail supply accounting system for the Marine Corps that provides functions, such as stock replenishment, requirements determination, receipts, inventory, stock control and asset visibility. SASSY maintains requisition and accountability files for both using units and intermediate levels of inventory (Jackson, 2009).

MIMMS is a standardized system providing for effective maintenance management related to organizational and intermediate maintenance throughout the Marine Corps. A variety of reports contain active maintenance and repair part information for effective maintenance production and engineering practices at all levels. Finally, MIMMS provides timely and accurate information on the equipment in the maintenance cycle (Jackson, 2009).

As of this writing, Marine Corps VAMOSC tracks 429 TAMCNs. Additionally, Marine Corps VAMOSC will not upload the most current MCBUL 3000 TAMCNs until after the FY09 closeout, usually in November.

F. MARINE CORPS EQUIPMENT READINESS INFORMATION TOOL (MERIT)

MERIT is a web-enabled tool that graphically depicts the current readiness posture and detailed supply and maintenance information for all Marine Corps readiness reportable TAMCNs. In November 2000, the Materiel Command, now known as MARCORLOGCOM, formed the Materiel Readiness Integrated Product Team (MRIPT), which brought together a cross-functional team that focused on material readiness policy, calculations, displays, reporting and procedures. MERIT has evolved and now transforms data into valuable information that provides a view of equipment readiness by commodity and functional area. MERIT gives Force Commanders visibility of their readiness trends, problems and associated causes. It also provides detailed information essential to maintainers, Logistics Management Specialists, Program Managers (PMs), and analysts. Material readiness is an issue that affects the entire Marine Corps, so the Marine Corps transitioned from a reactive to a proactive life cycle management process by implementing MERIT (MARCORLOGCOM, 2009).

MERIT recently created "Total Support Cost" to report O&I-level expenditures. Unlike VAMOSC, the Marine Corps updates MERIT daily. Additionally, Commanders can first look at broad readiness, but can also look at readiness and cost levels of subordinate units. Table 2 lists O&I level maintenance costs broken down by major commands (MARCORLOGCOM, 2009).

n

DESCRIPTION	SECREP PROC	REPAIR COST	TSC	CHANGE IN TSC	S	R	MR	CHANGE IN MR
Marine Corps Forces Spec Ops Cmd (0)	0	6,455,529	6,455,529	50.18%	81%	99%	81%	26.56%
I MEF Camp Pendleton, CA (1)	44,446,937	61,916,822	106,363,759	42.34%	91%	96%	89%	7.23%
II MEF Camp Lejeune, NC (2)	42,361,458	133,667,357	176,028,816	33.45%	91%	97%	90%	15.38%
III MEF Okinawa, JP (3)	10,105,747	10,354,975	20,460,722	-1.88%	91%	97%	89%	12.66%
IV Reserves (4)	9,227,741	10,911,440	20,139,180	40.66%	91%	97%	90%	18.42%
Hawaii (5)	0		0	-100%	100%	100%	100%	0%
MPS/MCPP-N (6)	0	49,882,366	49,882,366	192.15%	85%	99%	83%	31.75%
VII MEF (7)	46,440,708	30,450,799	76,891,507	-21.81%	95%	96%	93%	10.71%
Bases Posts and Stations (8)	0	23,032,768	23,032,768	18.76%	97%	95%	94%	3.3%
Unspecified (No MEF Specified)	0	53,254,632	53,254,632	0.81%	0%	0%	0%	0%
GRAND TOTAL	$ 152,582,591	$ 379,926,688	$ 532,509,279					

Table 2. Screenshot from MERIT Total Support Cost (From: MARCORLOGCOM, 2009)

After analyzing MERIT and VAMOSC, the decision was to focus on MERIT cost data. While both systems have well-defined filtering logic, the Marine Corps is more familiar with MERIT and trusts its capabilities.

G. LITERATURE REVIEW

This section examines the methodologies and findings of prior cost estimation studies, and discusses forecasting techniques. Table 3 displays a summary of each study.

Summary of Literature Review	
Section Title	**Section Description**
The Effects of Equipment Age on Spare Part Cost	No statistically significant evidence to support the claim that age has a positive effect on spare part cost.
Aircraft Age	Procurement cost and Aircraft age has a positive effect on maintenance workloads and part consumption.
Estimating Sustainment Costs	There are significant differences in the procurement to O&M ratios among commodities. Deployed TAMCNs require more maintenance. Unable to determine the age effect on O&M cost, submitting that USMC VAMOSC does not include enough data.
Budget Estimating Relationships for Depot-Level Repairables in the Air Force Flying Hour Program	Fighter aircraft missions result in more reparable expenditures than non-fighter missions do. Procurement cost, flying hours, aircraft age, and landings per sortie positively affect reparable cost. Average sortie duration negatively affects reparable cost.
Relationship between Usage and O&S Costs for Air Force Aircraft	When analysts forecast an increase in flying hours, planners should request less than a proportional increase in maintenance funds to fund other requirements.
Estimating U.S. Army O&S Cost Relations	OPTEMPO and acquisition costs drive O&S costs for U.S. Army ground vehicles.
An Analysis of O&S Costs for U.S. Navy Ships	Describes applicability of O&S techniques, and finds that personnel costs are highly correlated with O&S costs.
Stepwise Regression	Stepwise regression is a useful predictive (not explanatory) tool when the sample size is large.
Autoregressive Integrated Moving Average Forecasting (ARIMA)	ARIMA is useful for predicting general market developments, but not precise fluctuations.
Marine Corps O&M Budgeting Process	The Marine Corps does not employ quantitative models to forecast budgets for O&I level consumables and SECREPs.
Analyzing USMC O&I Level Part Charges	The top 20 TAMCNs consume 80-percent of maintenance expenditures, inventory positively affects maintenance costs, and maintenance cost data contains errors.

Table 3. Summary of Literature Review

1. The Effects of Equipment Age on Spare Part Cost

Fan et al. (2005) found no statistically significant evidence to support the claim that age has a positive effect on spare part cost for U.S. Army ground equipment. Fan analyzed M1A1 and M1A2 Abrams Tank data and argued that exogenous factors hinder a proper study of the age effect on the spare parts costs of the Abrams Tank. Fan concluded that analyzing more refined data might lead to evidence of an age effect. On the other hand, Fan argued that OPTEMPO and equipment location are worthy predictors of spare part cost.

Fan (2005) noted four factors that hinder a proper analysis of the effect of age on spare part costs. First, while field labor accounts for more than half of the Army's

maintenance cost, the Army does not capture labor cost as fully as it does spare part cost. Second, the parts budgeting process artificially reduces spare parts spending. Once a budget is set, it is nearly impossible for a unit to obtain funding increases. In addition, the Army does not track unfunded maintenance requirements. Third, Army units may go outside the normal supply system when funds are low. For example, instead of ordering a new part, a unit might ask a civilian or base mechanic to fix the defect, circumventing the Army supply system. As a result, the Army does not capture this data.

2. Aircraft Age

Pyles (2003) looked at the effects of aging aircraft on maintenance requirements, using up to 40 years of data. He cautioned that longer forecasts increase the potential for unforeseen factors to manifest themselves, causing an increase in the statistically necessary width of confidence intervals[5].

Pyles (2003) found that, in general, aircraft age has a positive effect on maintenance workloads. Additionally, he noted that procurement cost has a positive effect on maintenance workloads and part consumption. Finally, Pyle found that demand declines for General Support Division consumables after 20–40 years; however, he cautioned that he desired more years of data to confirm that the slight decline in demand was not actually demand leveling off.

3. Estimating Sustainment Costs

Klein (2005) found that the Marine Corps annually spends six to eight percent of a system's procurement cost on operations and maintenance (O&M). While he did not state that planners should rely on his study when defending budgets, his paper argues that procurement cost of the TAMCN should be one of many quantitative indicators in a planner's toolkit. Klein used Navy and Marine Corps VAMOSC data to conduct his research.

[5] Pyles also noted that the central limit theorem submits that independent variables may cancel each other out.

To enhance the credibility of his findings, Klein (2009) used data from MERIT’s Total Support Cost module, the Total Force Structure Management System (TFSMS) and the Total Life Cycle Management-Common Operating Picture, in addition to Navy and Marine Corps VAMOSC. Next, he examined the procurement to O&M ratios for groups of equipment. For example, communication TAMCNs may have different ratios than vehicle TAMCNs. Finally, Klein explored the effects of age, OPTEMPO and environment on O&M costs.

Klein (2009) concluded that there are significant differences in the procurement to O&M ratios among commodities. Additionally, he confirmed that deployed TAMCNs require more maintenance. Just as important, Klein cautioned that the procurement to O&M ratios among different TAMNCs of the same commodity often vary. In addition, he was not able to determine the age effect on O&M cost, submitting that USMC VAMOSC does not include enough data. Therefore, he did not conduct parametric cost analysis. As such, this paper uses Klein’s research as a platform for further analysis.

4. Budget Estimating Relationships for Depot-Level Repairables in the Air Force Flying Hour Program

Hildebrandt (2007) found strong predictors of depot-level repairable cost in the Air Force Flying Hour Program. First, fighter aircraft missions result in more repairable expenditures than non-fighter missions do. Additionally, procurement cost, flying hours, aircraft age, and landings per sortie positively affect repairable cost. As such, this analysis evaluates the effects of procurement cost, age, inventory, and other variables on maintenance cost. Next, he found that average sortie duration negatively affects repairable cost. Finally, Hildebrandt built regression models with and without serial correlation. He found that both models are statistically significant as a whole. Additionally, while the coefficients of his explanatory variables are slightly different in each model, the variables are the same sign and statistically significant in both models.

Hildebrandt (2007) systematically built and explained his regression model. First, he defined repairable cost and its measurement. Next, he compared then-year versus current-year dollar repairable expenditures. Then, he specified his model, discussing

reasons for including potential explanatory variables. In his discussion of variables, he noted each variable's trend over a multi-year period. Finally, Hildebrandt concluded with his model's limitations, including the need for more data before applying it to contingency environments. He also included the need to change the model when the Air Force changes its accounting rules.

5. Relationship between Usage and O&S Costs for Air Force Aircraft

When the relationship between OPTEMPO and O&S costs is not proportional, analysts should separate costs into their fixed and variable components (Unger, 2008). Unger found that the doubling of flying hours does not lead to the doubling of total O&S costs. Instead, Unger found that maintenance costs increase 56 percent when flying hours double. Unger argued that fixed costs are significant; therefore, analysts should separate O&S costs into their fixed and variable elements.

Unger (2008) addressed how to deal with high levels of multicollinearity. In his study, flying hours and inventory were so highly correlated that he could not easily determine which variable to include in his model. He chose flying hours, because there was a near perfect relationship between fuel consumption and flying hours. Therefore, he chose the explanatory variable most correlated with the dependent variable.

Unger (2008) concluded with recommendations for defense planners. When analysts forecast an increase in flying hours, planners should request less than a proportional increase in O&S funds to fund other requirements. More importantly, when analysts forecast a decrease in flying hours, planners should request less than a proportional decrease in funds to avoid a backlog. When dealing with an 11.5 billion dollar budget, maintenance funds keep over $400 million more in funding than following the traditional, proportional approach. Thus, Unger's research is most applicable during OPTEMPO transitions, which occur if OIF OPTEMPO reductions outweigh OEF OPTEMPO increases.

6. Estimating U.S. Army O&S Cost Relations

Hildebrandt and Sze (1990) found statistically significant relationships between OPTEMPO, acquisition cost and the O&S cost of ground vehicles, using the Army's OSMIS. They noted that OSMIS, unlike VAMOSC, does not capture Army personnel costs. While the OSD includes support personnel in its O&S cost definition, the Army does not include it in OSMIS because it views personnel costs as fixed. Hildebrandt and Sze grouped the Army's ground vehicles into three classes: (1) direct combat, (2) fire support, and (3) combat service support.

Hildebrandt and Sze (1990) used a log-linear ordinary least squares (OLS) model to develop cost-estimating relationships. They argued that a log-log model is ideal for many reasons. First, due to the intricacies of and correlation between their explanatory variables, a non-linear cost relation exists, which log-log OLS models can compute. Second, the coefficients of log-log models represent percentage changes in the dependent variable and are easy to interpret. Finally, log-linear models correct heteroskedasticity, which is a biased variance in the error term. Due to these factors, the authors also emphasize log-log models.[6]

Hildebrandt and Sze (1990) found a way to correlate design characteristics to O&S costs. While design characteristics and O&S costs are correlated, different design characteristics are highly correlated with each other, which results in the regression problem of multicollinearity. Therefore, Hildebrandt and Sze treated acquisition cost as an aggregate of design characteristics; thereby, replacing multiple explanatory variables with one. Additionally, Hildebrandt and Sze argued that acquisition cost is a valid O&S cost driver, because they viewed repair parts as a type of remanufacturing.

A direct combat vehicle's miles, rounds and acquisition cost have a positive effect on O&S costs (Hildebrandt and Sze, 1990). Additionally, Hildebrandt and Sze discovered a similar effect of OPTEMPO and acquisition cost on organizational level maintenance costs for Air Force fighter aircraft and Army direct combat vehicles. Next, for artillery

[6] We use log-log models instead of unit space models. Unit space models are the simplest models, listing all variables in their original form. For example, one would regress cost on inventory in a unit space model to determine the effect of a one-unit change in inventory on cost.

vehicles, the rounds variable has the strongest effect on O&S costs. In addition, the miles variable also has a positive effect on fire support O&S costs, but acquisition cost does not. Finally, combat service support vehicle O&S costs most strongly correlate with acquisition cost, although a statistically significant relationship between miles and O&S costs also exists.

7. An Analysis of O&S Costs for U.S. Navy Ships

Ting (1993) methodically built a model and identified personnel costs as having the strongest effect on O&S costs of U.S. Navy ships. First, Ting thoroughly validated his data source. Next, he specified his model, and identified and corrected for serial correlation, heteroskedasticity, and outliers. Lastly, Ting provided analysts with a tool to use when forecasting the impact of changing variables like OPTEMPO and personnel requirements on O&S costs.

Ting used the following four-step process to validate his data: "(1), grouping data, (2) specification of each group, (3) use of robust regression method, and (4) treating serial correlation and heteroskedasticity as factors that need to be addressed in pooled datasets" (1993, p. 8). This paper discusses Ting's first two steps. First, Ting grouped his data into 10 classes of ships. Ships in the same class have similar OPTEMPO and weights. Next, he identified missing values to verify whether he had enough observations to continue. Ting found very few unexplainable values missing and had sufficient data to continue.

Finally, Ting specified his model and ran regressions to validate the data from each class of ship. For example, he naturally concluded that personnel costs are a function of enlisted costs and officer costs. Additionally, because officers make more money than enlisted personnel do, Ting concluded that the coefficients of officers should be greater than enlisted and both should be positive. Therefore, Ting removed one of the classes of ships because the coefficient of enlisted personnel was greater than that of officers. Ting used this technique with OPTEMPO, maintenance costs, and overhaul and removed one additional ship class. Thus, Ting's methods improved the credibility of his findings.

8. Methods of Statistical Analysis

This section identifies and describes several methods of statistical analysis. This methodology chapter explains the applicability of these methods to the performance-cost problem that this thesis addresses.

9. Stepwise Regression

Stepwise regression can be useful for quickly developing predictive models, but it has a high potential for misuse (Robbins & Daneman, 1999). Analysts might use stepwise regression after developing a correlation matrix for the potential independent variables, and in conjunction with standard or hierarchical multiple regression. Finally, analysts should only use stepwise regression as a sole technique under specific circumstances, as described below.

In stepwise regression, computer programs add and delete variables one at a time, based on their degree of added variance explanation, which can be measured by the 'F' or 'partial R' statistic (Robbins & Daneman, 1999). Computer programs add and delete the same variables, regardless of the order that the analyst inputs. Thus, stepwise regression is a quick and easy technique that analysts can add to their toolkits.

Robbins and Daneman (1999) concluded that analysts should only use stepwise regression as their sole method under three circumstances.

- The research goal should primarily be to develop a predictive model. Analysts may only use it as a secondary or tertiary explanatory model.
- The sample size should be at least 40 times as large as the number of explanatory variables.
- Analysts should validate their stepwise regression model by randomly splitting their sample size in half.

10. Autoregressive Integrated Moving Average Forecasting (ARIMA)

Stevenson (2007) analyzed the forecasting ability of autoregressive integrated moving average (ARIMA) models in a civilian setting that focused on the prediction of

property rents.[7] Stevenson structured his article into five parts: an introduction, data requirements and methodology, forecasting evaluation, comparative forecasting accuracy, and concluding comments. Stevenson's introduction includes a literature review, his objective, and a roadmap of his article. In data requirements and methodology, Stevenson noted the two data indices he used, and he explained how the ARIMA model forecasts property rents. In forecasting evaluation, Stevenson showed that an ARIMA model's forecasting power depends on the data index used. In comparative forecasting accuracy, Stevenson explained the relative strengths and weaknesses of each data index. Finally, in his concluding comments, Stevenson summarized his findings and warned the reader of ARIMA's limitations (Stevenson, 2007).

Stevenson studied whether "in-sample measures of best-fit and also past forecasting accuracy bear any relation to future forecasting performance" (2007, p. 223). Stevenson aimed to use ARIMA models to test whether analysts should rely on historical data to predict future outcomes. The current economic recession adds relevance to Stevenson's article. Currently, many financial experts (Olander et al., 2009) believe that influential economists and leaders have relied too much on quantitative models, which contributed to the recent global financial meltdown. In addition, Stevenson's research question is significant, because not answering it keeps one from more thoroughly understanding ARIMA's limitations (Booth, Colomb & Williams, 2008).

Stevenson (2007) conducted a thorough literature review in the introduction, citing 15 different references. Stevenson cited both users and critics of forecasting techniques. For example, he noted that in the 1980s, scholars used mostly ordinary least squares models that relied on explanatory variables. Then, he discussed the use of ARIMA models in the 1990s, which were simple and did not rely on explanatory variables. As such, analysts used ARIMA models less for explaining and almost exclusively for predicting outcomes. Finally, Stevenson cited scholarly criticism of ARIMA models. He used the continued controversy over the use of ARIMA models to justify his examination of the topic in more detail.

[7] ARIMA models use lagged forecast residuals and a dependent variable's lagged values to forecast future values.

In addition, Stevenson cited experts to explain the need to use two different data indices. For example, he used the Jones Lang LaSalle Rent Index (JLL) because its property appraisers value actual properties. However, the appraisers gather data over a quarter, which incorporates the data into an artificially “smoothed element” (Stevenson, 2007, p. 224). On the other hand, he used the CB Richard Ellis Prime Rent Index (CBREPRI) because its collectors pull their data at one point in time. However, the CBREPRI values hypothetical properties. Therefore, based on the literature, Stevenson anticipated criticism by using both types of indices to evaluate his ARIMA models.

Stevenson (2007) described the mechanics of forecasting with ARIMA models. First, he defined ARIMA’s components. Next, he described how he would evaluate the 15 different ARIMA models that he would produce. He noted that there are two widely used criteria to evaluate forecasting methods, and discussed the merits and limitations of each method. Stevenson again anticipated criticism by using both criteria to evaluate his models. Additionally, Stevenson indicated that the ARIMA model may perform poorly at predicting shifts, due to only four shifts in the data out of 60 possibilities.

Stevenson next linked his results with his original research question. First, he explained his findings, citing that ARIMA models performed differently, based on which index he used. For example, Stevenson noted that the ARIMA model that performed best in eight of the eleven periods using the JLL index performed worst in six of eleven periods using the CBREPRI. Next, Stevenson used this evidence to support one of his reasons for cautioning against blindly using ARIMA models. Stevenson also used evidence to highlight strengths of ARIMA models. For example, he noted that ARIMA models are better suited for forecasting values using the JLL index, and that they are even better at predicting market shifts using the CBREPRI. Therefore, Stevenson concluded that ARIMA models might be useful for predicting shifts in rents, which is important to analysts (2007).

Stevenson also related his findings to preexisting literature and research studies. For example, he cited a previous study that criticized ARIMA models for consistently under predicting rents. By using the CBREPRI, he demonstrated that ARIMA models

might actually over predict rents more often than under predict them. In addition, he stated that his results were weaker than another scholar's results in terms of rank correlation (2007).

Stevenson spent most of his analysis discussing the statistical significance of his results. In fact, he created a table that discussed statistical significance at the ten, five and one percent levels. However, Stevenson also argued that his findings have practical significance as well. He stated that ARIMA models are helpful in forecasting broad shifts, but that previous forecasting strength does not correlate with future forecasting ability. Finally, he argued that the JLL data might mislead users, because of their smoothing element.

Stevenson used his results to provide three new takeaways. First, ARIMA models can be helpful in predicting general market developments, such as growth and downturn. On the other hand, analysts should not rely on ARIMA models to forecast precise market changes. Thus, macro-level forecasters should benefit more from ARIMA models than micro-level forecasters should. Finally, Stevenson highlighted the need for analysts to carefully select and scrutinize data, even if academics and professionals consider the data credible.

11. Marine Corps O&M Budgeting Process

The Marine Corps does not employ quantitative models to forecast budgets for O&I level consumables and SECREPs. Instead, the Marine Corps uses the "Budget Call" (Miller, 1999, p. 45) and "Budget Review" (Miller, 1999, p. 46) processes to a formulate budget estimate submissions from the program objective memorandum. In the former process, the Program and Resources (P&R) department of HQMC provides a budget ceiling to and requests budget plans from MARFOR Commands. MARFOR Commands require battalion sized units and higher to submit budget requests. In the latter process, P&R reviews budget submissions for reliability and conformity to the aggregate USMC budget. P&R might consider the more extensive use of quantitative forecasting techniques, such as those developed in this thesis, during its review process to enhance the credibility and defensibility of its budget to the DoD and Congress.

12. Analyzing USMC O&I Level Part Charges

Kelly (2009) completed an initial analysis of USMC O&I maintenance costs.[8] Using raw MIMMS and SASSY data from FYs 2005 to 2008, Kelly (2009) organized his study into two phases, and used descriptive statistics to develop a preliminary forecasting tool for HQMC I&L.

a. Phase One: Annual MARFOR Maintenance Costs per TAMCN

Phase one attempted to assist planners in analyzing past O&I parts expenditures as part of the MARFOR's annual budget requests (Kelly, 2009). First, Kelly created data worksheets for each Marine Corps Bulletin (MCBUL 3000) TAMCN broken down by the various MARFOR's. Next, he populated each worksheet with annual O&I level consumables, SECREPs and maintenance costs, using FY 2008 constant dollars. He then summarized the O&I level maintenance costs for each FY. Additionally, he identified which TAMCNs consumed the majority of the O&I maintenance budget. Finally, Kelly calculated the mean and standard deviation of the TAMCN maintenance costs, and advised budget reviewers to question budgets that fall outside the standard deviation limits.

b. Phase Two: Annual MARFOR Maintenance Costs per Inventory of TAMCN

During phase two, Kelly divided the total O&I level maintenance costs by the number of MARFOR-possessed TAMCNs. For example, if MARFORPAC spent $100M on O level maintenance for High Mobility Multipurpose Wheeled Vehicles (HMMWVs) and possessed 25, then on average, MARFORPAC spent $4M on O level maintenance per HMMWV. Finally, he calculated the mean and standard deviation of the maintenance costs, and advised budget reviewers to question budgets that fall outside the standard deviation limits.

[8] LCDR Kelly included labor charges during both phases of his analysis.

H. CONCLUSIONS

Three of Kelly's (2009) findings are significant to the current phase of this study.

- Twenty TAMCNs (not always the same 20) incur approximately 80 percent of the Marine Corp's maintenance expenditures.
- There is a positive, although highly variable relationship, between TAMCN inventory levels and total maintenance expenditures.
- Data from 2002–2004 overstate actual expenditures and could not be included in his study.

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III. MARINE CORPS MAINTENANCE PROCESS

A. USMC MEF STRUCTURE

The United States Marine Corps is currently broken down into eight Marine Expeditionary Forces (MEFs). This thesis only focuses on MEFs I–V, which comprise MARFORPAC, MARFORCOM, and MARFORRES.

- I MEF California (**MARFORPAC)**
- II MEF North Carolina (**MARFORCOM)**
- III MEF Okinawa (**MARFORPAC)**
- IV MEF New Orleans (**MARFORRES)**
- V MEF Hawaii (**MARFORPAC)**
- VI MEF Blount Island Command
- VII MEF Iraq/Afghanistan
- VIII MEF Bases, Posts, and Stations

B. THE MARINE CORPS MAINTENANCE PROCESS

The Marine Corps maintenance process is broken down into three pillars: (1) organizational (using unit) level; (2) intermediate level; and (3) depot level. Each pillar is authorized to perform specific levels of maintenance.[9]

C. EQUIPMENT REPAIR ORDER (ERO)

Organizational and intermediate part charges for consumables and SECREPs is the focus of this thesis, so understanding the process between the using unit and the intermediate maintenance activity is crucial. The using unit is equipped with an organic

[9] MARADMIN 583/03 defines the three pillars of maintenance as follows: **Organizational Level:** Includes expeditious assessment and maintenance conducted under battlefield conditions…**Intermediate Level:** Include inspection/in-depth diagnosis, modification, replacement, adjustment, and limited repair or evacuation/disposal of principal end items and their selected reparables and components/sub-components. **Depot Level:** Sustains equipment throughout its life cycle by performing major repair, overhaul, or complete rebuild of parts, subassemblies, assemblies or principal end items to include manufacturing parts and conducting required modifications, testing calibrating, and reclaiming.

maintenance and supply capability. An Infantry Battalion is an example of a using unit activity. When a TAMCN is inducted into the maintenance cycle at the using unit level, the maintenance personnel must first determine what the defect is. If they can fix the problem at the using unit level, then they open an Equipment Repair Order (ERO). If they cannot fix the problem, then the TAMCN is evacuated to the Intermediate Maintenance Activity (IMA). An ERO is a data sheet that a maintainer creates for maintenance tracking purposes. An ERO lists the type of maintenance required and the consumable parts required to fix the problem. Each ERO is assigned a unique ERO designation number similar to a personal identification number. Figure 1 is an example of an ERO worksheet. As the maintenance personnel draft the ERO, they are also simultaneously drafting an Equipment Repair Order Shopping List (EROSL). The EROSL lists all the consumable parts required to fix the open ERO. This EROSL is then given to the using unit supply shop for parts requisitioning.

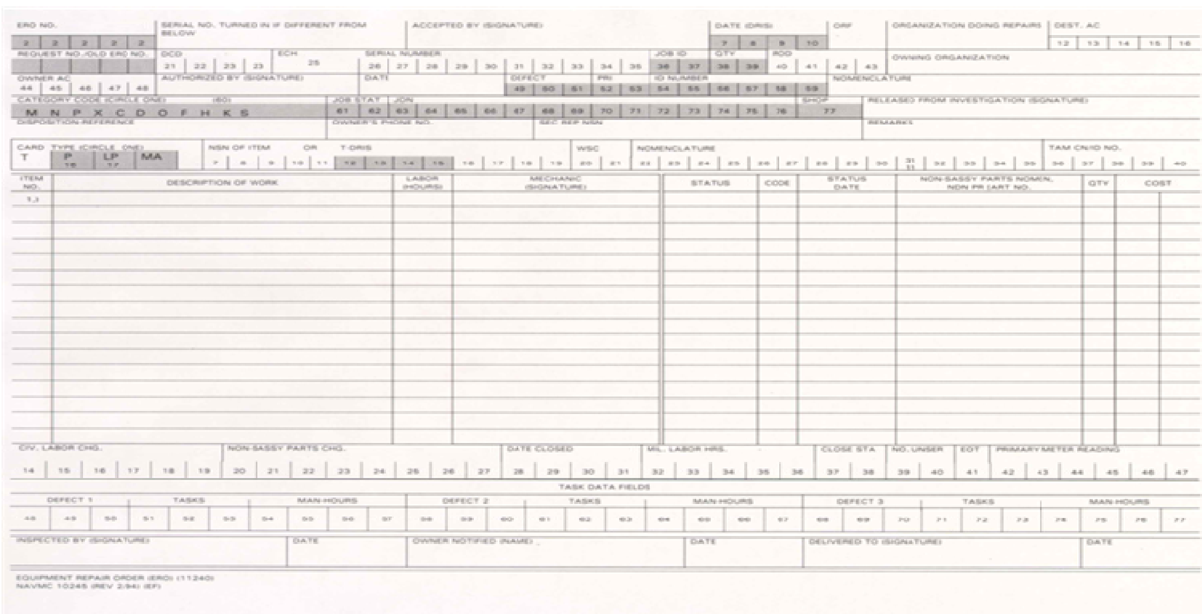
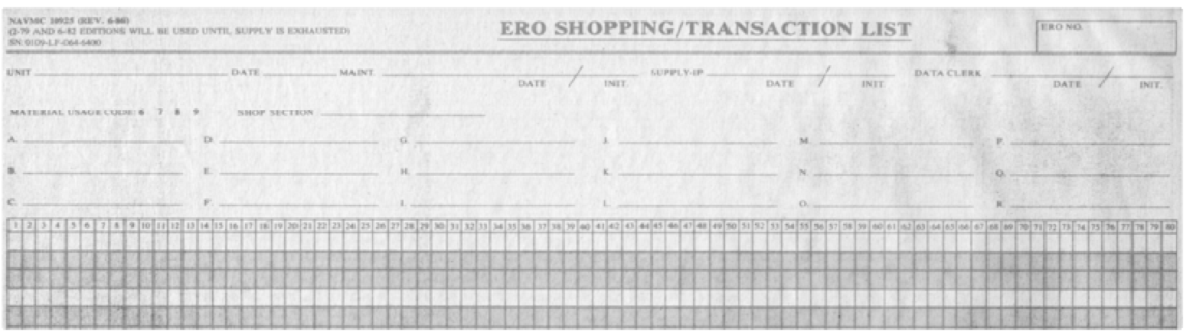

ERO NO. | SERIAL NO. TURNED IN IF DIFFERENT FROM BELOW | ACCEPTED BY (SIGNATURE) | DATE (DRIS) | ORF | ORGANIZATION DOING REPAIRS | DEST. AC
REQUEST NO./OLD ERO NO. | DCD | ECH | SERIAL NUMBER | JOB ID | QTY | POD | OWNING ORGANIZATION
OWNER AC | AUTHORIZED BY (SIGNATURE) | DATE | DEFECT | PRI | ID NUMBER | NOMENCLATURE
CATEGORY CODE (CIRCLE ONE) (60) M N P X C D O F H K S | JOB STAT | JON | SHOP | RELEASED FROM INVESTIGATION (SIGNATURE)
DISPOSITION REFERENCE | OWNER'S PHONE NO. | SEC REP NSN | REMARKS
CARD TYPE (CIRCLE ONE) T P LP MA | NSN OF ITEM OR T-DRIS | WSC | NOMENCLATURE | TAM CN/ID NO.
ITEM NO. | DESCRIPTION OF WORK | LABOR (HOURS) | MECHANIC (SIGNATURE) | STATUS | CODE | STATUS DATE | NON-SASSY PARTS NOMEN. NON PR (ART NO. | QTY | COST
CIV. LABOR CHG. | NON-SASSY PARTS CHG. | DATE CLOSED | MIL. LABOR HRS. | CLOSE STA | NO. UNSER | EOT | PRIMARY METER READING
TASK DATA FIELDS
DEFECT 1 | TASKS | MAN-HOURS | DEFECT 2 | TASKS | MAN-HOURS | DEFECT 3 | TASKS | MAN-HOURS
INSPECTED BY (SIGNATURE) | DATE | OWNER NOTIFIED (NAME) | DATE | DELIVERED TO (SIGNATURE) | DATE
EQUIPMENT REPAIR ORDER (ERO) (11240)
NAVMC 10245 (REV 2/94) (EF)

Figure 1. Equipment Repair Order (ERO) (From: USMC, 1995)

The using unit supply shop has the responsibility for placing all consumable parts on order, so the using unit maintenance shop can keep equipment readiness up. When the supply shop receives an EROSL from the maintenance shop, it immediately keypunches the transactions, which are then submitted through a currier to the SASSY Management

Unit (SMU) for further processing. The SMU falls under the Marine Corps Logistics Groups (MLG) Supply Battalion and warehouses all classes of supply. The SMU is considered the one stop shop for consumable repair parts to all ground units. Once the SMU receives the order, it checks its stock levels and if it has the parts on-hand, it immediately coordinates to have the parts shipped back to the supply shop. If it does not have the parts on-hand, the parts are placed on backorder and delivered once they arrive to the SMU. When the supply shop receives the consumable repair parts, it immediately transfers the parts to the maintenance shop. Finally, the maintenance shop closes the ERO when it fixes the TAMCN and deems it serviceable. Figure 2 is an example of an EROSL.


ERO SHOPPING/TRANSACTION LIST

ERO NO.

UNIT DATE MAINT. DATE / INIT. SUPPLY-IP DATE / INIT. DATA CLERK DATE / INIT.

MATERIAL USAGE CODE: 6 7 8 9 SHOP SECTION

A. D. G. J. M. P.

B. E. H. K. N. Q.

C. F. I. L. O. R.

Figure 2. Equipment Repair Order Shopping List (EROSL) (From: USMC, 1995)

D. REPAIRABLE ISSUE POINT

The Repairable Issue Point (RIP) manages all SECREP items for ground equipment throughout the Marine Corps. SECREPS are considered high dollar items that can normally be fixed once they break. They are separated into two categories: (1) ground SECREPS, and (2) low density SECREPS. Examples of ground SECREPS include HMMWV transmissions and engines. Examples of low density SECREPS include satellite circuit cards and circuit boards. SECREPS cannot be repaired at the using unit level since they do not maintain this capability. When a SECREP breaks, the using unit maintenance shop takes the broken SECREP to the RIP and, if the RIP holds the part in inventory, there is one-for-one swap. If it does not possess the necessary part, three courses of action can be taken in which it can replenish or replace the broken

SECREP. The three courses of action include the intermediate maintenance activity (IMA), the Materials Return Program (MRP), and the Logistics Integrated Support (LIS) contractor.

1. Intermediate Maintenance Activity (IMA)

The IMA is normally the first course of action the RIP pursues in getting the SECREP fixed. If the IMA is able to fix the SECREP, the item immediately goes back on the RIP's shelf as serviceable stock. If the IMA is unable to fix the SECREP, the item is then returned to the RIP to pursue another course of action.

2. Materials Return Program

The MRP process is another alternative that the RIP pursues. At this time, the RIP is given disposition instructions for the unserviceable SECREP by the source of supply. In return, the source of supply provides a credit to the RIP. This credit is then transferred back to the RIP's budget and can be applied to the purchase of additional SECREPS. Initially, the RIP pays the full unit price for the SECREP. The source of supply then determines the exchange price based on the condition and reparability of the unserviceable SECREP. MARCORLOGCOM in Albany, GA determines the exchange price. This is similar to turning in your unserviceable car battery to the auto shop and given a credit applicable to the purchase of a new battery.

3. Logistics Integrated Support Contractor

The LIS contractors, currently Raytheon and Oshkosh, are partnered with the RIPs to provide services such as materials acquisition for SECREPS, maintenance overhaul, and the remanufacture of parts (Raytheon, 2007; Oshkosh, 2006). When either the IMA or MRP process is unsuccessful or costly, the LIS contractors are then responsible to fix that same unserviceable SECREP. The Marine Corps does not possess adequate capabilities to fix all SECREPS. Thus, contractor support is a necessity.

Figure 3 illustrates the O&I maintenance process concerning consumables and SECREPs.

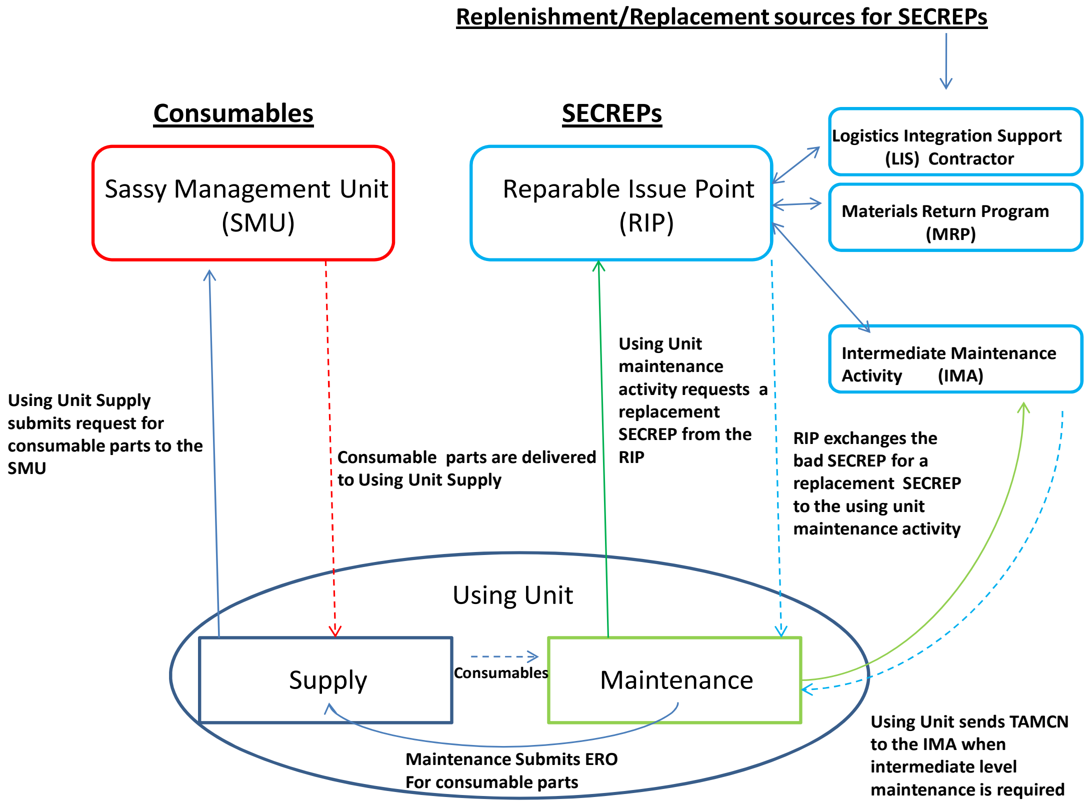


Figure 3. O&I Maintenance Process

4. Organizational and Intermediate Level Budget Process

When annual Operations and Maintenance budgets are approved, funds are transferred from the Department of the Navy to HQMC I&L. HQMC I&L then pushes the funding to the MARFORs and down to the MEFs. The MEFs are then responsible for breaking down these funds further to the division, wing, and the MLG. Each division, wing, and MLG then breaks down those funds further until they reach the using unit level.

The using unit activity and the IMA are given annual O&M funds for maintenance expenditures. These funds are based on internal budget requests from supply and maintenance personnel. Using historical data, supply and maintenance personnel estimate their future requirements to create a base line budget request. This baseline

budget request is then submitted up the chain of command until all budget requests are consolidated at the MEF level. Once these budgets requests are approved, they are then forwarded to the MARFOR level.

The using unit activity is authorized to perform first and second echelon maintenance if a TAMCN is rendered unserviceable. Any consumable parts ordered for that TAMCN via the EROSL are charged to that using unit activities budget. If a TAMCN cannot be fixed at the using unit level, that TAMCN is then evacuated to the IMA. It is the responsibility of the IMA to fix that TAMCN and pay for its repair parts. The using unit activity is not charged for the maintenance repairs once the TAMCN is evacuated to the IMA.

5. RIP Funding

The RIP receives O&M funds for the replenishment and replacement of SECREPS. All SECREPS currently on the RIP's shelves are already owned by that MEF. When a unit turns in an unserviceable SECREP to the RIP, they conduct a one-for-one swap. The unit that turned in the unserviceable SECREP is not charged for the replacement of the serviceable SECREP.

The IMA is usually the first course of action for the RIP when there is an unserviceable SECREP. If the IMA is able to fix the SECREP, then they pay for the repairs using its own O&M funds. The IMA's submit a yearly budget for future maintenance expenditures based on historical data.

The RIP uses its own O&M funds when the IMA is unable to fix an unserviceable SECREP. Using the MRP process, the RIP determines the appropriate source of supply for the replacement SECREP and initiates the buy transaction known as a ZRB SASSY transaction. The RIP pays full price for the SECREP and is given disposition instructions for the unserviceable SECREP. The source of supply determines the amount of credit the RIP receives for the unserviceable SECREP. Once the credit amount is determined, that amount of funding is returned back to the RIP's O&M budget. Normally, the source of supply for the Marine Corps is MARCORLOGCOM.

The RIP's third option for the repair of an unserviceable SECREP is to use LIS contractors. If the RIP determines that it is cost effective to use these contractors, they then hand them off the unserviceable SECREPs. The RIP keypunches a ZBE SASSY transaction to release the unserviceable SECREP to the contractor. A Military Interdependent Purchase Request (MIPR) is used to pay the contractor. A MIPR authorizes funds to an external agency that can perform the required work or service (MCO 7300.21A). This funding is then obligated and liquidated from the RIPs O&M budget. Figure 4 illustrates the budget process for consumable and SECREP part charges.

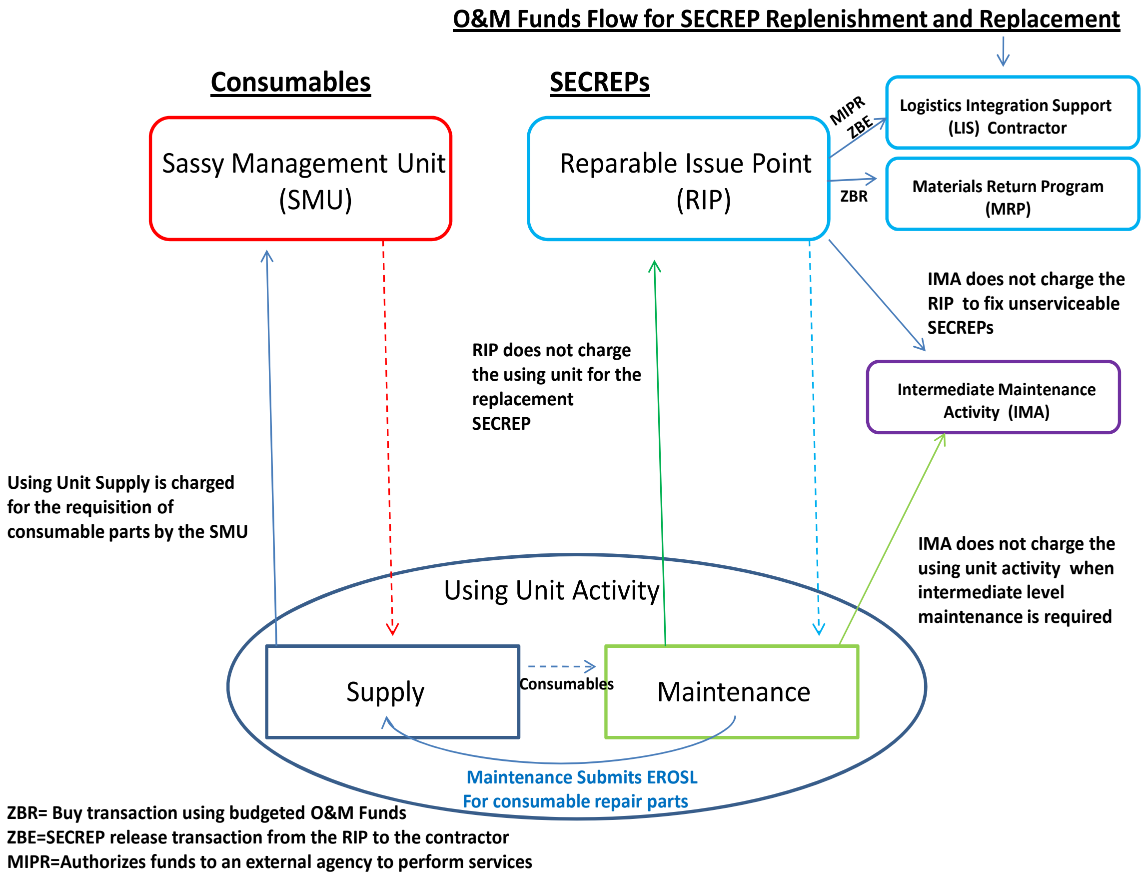


Figure 4. O&M Funds Flow for SECREP and Consumable Replenishment and Replacement

E. THE STANDARD ACCOUNTING, BUDGETING AND REPORTING SYSTEM (SABRS)

The official accounting system for the Marine Corps is SABRS (MCO 7300.21A 2008). The purpose of SABRS is to track the Marine Corps' expenditures of goods and services. "SABRS interfaces with SASSY and MIMMS to capture document numbers for repair parts and accountable items that were ordered, receipted for, or canceled" (MCCSSS 2004, p. 3). This system informs the end user how much funding is obligated and liquidated along with the current remaining funding balance.

IV. METHODOLOGY AND DATA SOURCES

A. METHODOLOGY

This thesis aims to identify and explain maintenance part charge drivers (i.e., explanatory variables), and develop an Autoregressive (AR) model to forecast part charges at the MARFOR level. The primary goal is to construct a statistically significant performance-cost estimating model. This study emphasizes the use of a policy response model. It also develops a log-log-linear model to explain part charges, using SPSS, a statistical software package. Gilster (1970) explains that a policy response model can enable policy makers to determine the likely effects of alternative shifts in policy on the dependent variable. The value of a policy response model relies on the dependence of criterion variables on undetermined policy variables, while the value of a forecasting model depends on the least error (Gilster, 1970). Even if a model has a low R^2, but has highly significant explanatory variable coefficients, the effects on the dependent variable can still be explained and should not be detracted from the value of the model (Gilster, 1970). The two most likely reasons for the simultaneous combination of a low R^2 and highly significant variables are that significant factors are outside the model, and randomness.

The secondary goal of this thesis is to introduce a forecasting technique to use when prediction is the goal. This study creates a suitable predictive model to forecast actual part charge expenditures in future years. This study defines part charges as the sum of consumable and SECREP part charges.

B. DEPENDENT VARIABLES

This thesis examines three dependent variables: consumable part charges, SECREP part charges and the sum of consumable and SECREP part charges. This study defines ‘part charges’ as the sum of consumable and SECREP part charges. MERIT provided consumable and SECREP part charge data for FY 2005–2008, organized by TAMCN, MEF, and year. First, these charges are converted to FY 2008 dollars using

NCCA inflation indices. Second, MEFs I, III and V are categorized as MARFORPAC, MEF II as MARFORCOM, and MEF IV as MARFORRES. Finally, the natural log (LN) of the part charges is computed, which facilitates the discussion in terms of percentage changes instead of unit changes.

MERIT data was used instead of the raw MIMMS and SASSY data for a variety of reasons. First, Kelly (2009) found that the raw MIMMS and SASSY data overstated actual expenditures from 2002–2004 (2009).[10] Second, MERIT data professionals process the data. Third, Marine Corps leaders have been using MERIT for over five years, increasing its credibility. Finally, the authors decided that MIMMS and SASSY include only consumable part charges.[11]

Consumable part charges were defined as the amount of money a MARFOR spends on consumable parts inducted into the maintenance cycle in one fiscal year. Units replace consumable parts when broken; units do not repair consumable parts. Ball joints and mirrors are examples of consumable parts.

SECREP part charges were defined as the amount of money a MARFOR spends on SECREPs for any given MCBUL 3000 TAMCN in one fiscal year. A SECREP is a component of the end item and not functional by itself (MCO P4790.2C, p. 62). Engines and transmissions are two examples of SECREPs.

- **Sum of SECREP and consumable part charges (i.e., part charges)**: the amount of money a MARFOR spends on SECREPs and consumable parts for any given MCBUL 3000 TAMCN in one fiscal year.

C. INDEPENDENT VARIABLES

The independent variables used in the regressions include the following: LN part charges on LN inventory, LN average TAMCN cost, LN Mean Days Between

[10] In 2002–2004, the raw MIMMs and SASSY data erroneously contained extended prices (quantity times a part's unit price) in the unit price column of consumable parts. Therefore, when one multiplied the extended price by the actual price, he obtained a number erroneously higher by a factor of the quantity ordered. For example, if a unit ordered three engines for $30 each, the unit price would read "$90," and the quantity ordered would read "3." Consequently, the model would record $270 in part charges, instead of the actual amount of $90.

[11] MIMMS and SASSY data likely includes only part charges to repair SECPREPs at the IMA when calculating SECREP part charges, while MERIT also includes SECREP procurement charges.

Maintenance (MDBM), Average initial operational capability (IOC) year, Alpha TAMCN group indicator variable, Bravo TAMCN group indicator variable, Charlie TAMCN group indicator variable, Delta TAMCN group indicator variable, SECREP indicator variable, MARFORRES indicator variable, tracked vehicle indicator variable, and armored personnel carrier (APC) indicator variable. IOC year is in unit form to enable discussing the effect of a one-year change instead of a percentage-year change to increase clarity. Some explanatory variables, especially indicator variables, include only a limited number of TAMCNs. This thesis includes only the 2009 MCBUL 3000 TAMCNs. With this introduction, note the following independent variables.

- **Inventory:** the quantity of a TAMCN that a MARFOR possesses at a fixed point in time in one fiscal year. MARCORLOGCOM provided the TAMCN inventory data.
- **Average TAMCN cost:** the average cost of a TAMCN. When TAMCNs include more than one variant, the average variant cost represents the average TAMCN cost. MARCORSYSCOM provided this data in FY 2009 dollars, which were converted to FY 2008 dollars for the sake of direct comparability with parts cost.
- **MDBM:** the average amount of days a TAMCN is operational (i.e., not in the maintenance cycle). MDBM is measured by ERO open and close dates for the same TAMCN. MDBM provides an indication of reliability. An increase in MDBM means that a TAMCN remains operational for a longer duration. MARCORSYSCOM provided this data using the System Operational Effectiveness (SOE) application.
- **Average IOC year:** the average IOC of a TAMCN. There is not an accurate measure of age. However, Average IOC, which shows costs declining as IOC increases, can also be capturing some aging. If equipment with IOC years prior to the data set shows high part charges in recent years, this could be caused in part by aging. However, because costs may decline when Average IOC increases, there could also be a technological-enhancement component to this variable. To compute an ideal age variable, one needs both a TAMCN’s fielding and disposal schedule, which are not readily available. When TAMCNs include more than one variant, the average variant’s IOC represents the average TAMCN IOC. TFSMS provided this data.
- **Alpha, Bravo, Charlie, and Delta TAMCN group indicators:** the effect of the TAMCN category on part charges, using the Echo TAMCN indicator as the reference variable. For example, only Alpha TAMCNs receive a value of “1” under than Alpha indicator variable, all other TAMCNs receive a value of “0.”

- **SECREP indicator:** this variable analyses whether or not a TAMCN with SECREP charges results in significantly different total part charges than TAMCNs with only consumable charges. For each MARFOR, only MCBUL 3000 TAMCNs with SECREP part charges receive a value of "1" under the SECREP indicator variable.
- **MARFORRES indicator:** this variable analyses whether or not a MARFORRES TAMCN results in significantly different part charges than a TAMCN in MARFORPAC or MARFORCOM. All MCBUL 3000 TAMCNs with parts charges in MARFORRES receive a value of "1," while MARFORPAC and MARFORCOM receive a "0."
- **Tracked vehicle indicator:** this variable analyses whether or not tracked vehicles result in significantly different part charges than all other TAMCNs. All MCBUL 3000 TAMCNs classified as tracked receive a value of "1," while all other TAMCNs receive a value of "0." Tracked vehicles include tanks, tank recovery vehicles, and the three types of amphibious assault vehicles (e.g., personnel, command, and logistics).
- **APC indicator:** this variable analyses whether or not APCs result in significantly different part charges than all other TAMCNs. All MCBUL 3000 TAMCNs classified as APCs receive a value of "1" under the APC indicator variable. APCs include the up-armored HMMWV, armored 7-tons, AAVs, and Light Assault Vehicles.

TAMCN Make-up of Explanatory Variables

Alpha		
A0013	A0882	A2077
A0020	A0921	A2078
A0021	A0932	A2079
A0025	A0966	A2152
A0067	A1225	A2179
A0068	A1260	A2390
A0069	A1380	A2525
A0075	A1440	A2533
A0116	A1500	A2535
A0124	A1503	A2538
A0126	A1520	A2551
A0139	A1818	A2555
A0254	A1954	A2560
A0255	A1955	A2628
A0425	A1957	A2634
A0499	A2042	A3232
A0806	A2044	A3252
A0807	A2068	A3270
A0814	A2070	A8019
A0873	A2075	A8038
A0880	A2076	

Bravo	
B0001	B0980
B0008	B1016
B0012	B1021
B0014	B1045
B0035	B1082
B0114	B1135
B0152	B1315
B0155	B1580
B0392	B2085
B0476	B2086
B0589	B2127
B0675	B2462
B0685	B2483
B0730	B2561
B0891	B2566
B0921	B2567
B0953	B2605
B0971	

Charlie
C2278
C2282
C5649
C5901

Delta	
D0001	D0235
D0003	D0861
D0004	D0876
D0005	D0877
D0006	D0878
D0007	D0880
D0008	D0881
D0009	D1001
D0013	D1002
D0015	D1062
D0022	D1063
D0025	D1064
D0027	D1073
D0030	D1125
D0033	D1158
D0198	D1159
D0209	D1160
D0215	D1213

Echo	
E0020	E0950
E0149	E0980
E0150	E0984
E0180	E0989
E0207	E0994
E0311	E1030
E0330	E1065
E0665	E1095
E0671	E1145
E0796	E1210
E0846	E1378
E0856	E1460
E0915	E1475
E0935	E1500
E0942	E1839
E0946	E1888
E0947	E1906
E0948	E1976
E0949	

APC	
D0001	E0856
D0005	E0942
D0006	E0946
D0025	E0947
D0027	E0948
E0796	E0949
E0846	E0950

Tracked
E0796
E0846
E0856
E1378
E1888

Table 4. TAMCN Make-up of Explanatory Variables

D. AUTOREGRESSIVE (AR) FORECASTING MODEL

This study also introduces a forecasting method to use when the goal is prediction instead of policy response. An Autoregressive (AR) model is created, which uses cross-

section, time series data to predict future part charges in MERIT. This study's AR model considers serial correlation among the residuals.[12] This study takes the following steps to develop an AR model forecast.

- Use SPSS to create an AR model
- Predict future value of explanatory variables by using their values in previous years to predict the values in 2009 and 2010. This assumes that a variable's past value affects its future value. If unable to predict future values, use 2008 values.
- For 2009, multiply each data point by the $\hat{\rho}$ given in the AR model output. For 2010, multiply by $\hat{\rho}^2$.
- Exponentiate predicted values for 2009 and 2010.
- Multiply totals by the $\exp\left(\frac{\textit{standard error of the estimate}^2}{2}\right)$ to eliminate the bias that results when a log dependent variable is only exponentiated (Wooldridge, 2008).
- For each MARFOR, sum the total predicted consumable and SECREP part charges in the two forecasting levels across TAMCNs in each forecasting year.
- Make adjustment when exponentiating.

Multiple data sources were used to comprise the database used in this thesis for regression analysis. Table 5 lists the sources used along with the variables derived from these sources. There is not a single source or location that could have been used to extract the necessary data for this study. If future studies are to be conducted concerning the Marine Corps O&I part charge expenditures, having a single source to extract data from would be beneficial. The data already exists; it is a matter of compiling the data into a user-friendly database source.

[12] The model is $u_{t,i,j} = \rho u_{t-1,i,j,N}$ where 'i' stands for MARFOR and 'j' for TAMCN. The 'ρ' is assumed not to depend on 't', 'i', or 'j'. This assumption constitutes the simplest forecasting model that builds on the estimated policy response model.

DATA SOURCE	VARIABLE
MARCORSYSCOM (USMC SOE ANALYSIS)	MDBM
MCBUL 3000	TAMCN TYPE (A,B,C,D,E)
MARCORSYSCOM (MIMMS/SASSY)	TAMCN UNIT COST and INVENTORY, BOTH BY MARFOR, FY
MARINE CORPS COMBAT DEVELOPMENT COMMAND (TFSMS)	IOC YEAR
MARINE CORPS VAMOSC	OPTEMPO[13]
MARCORLOGCOM (MERIT)	PARTS COST, SECREP COST

Table 5. Data Sources

[13] OPTEMPO was initially included in the OLS policy response model; however, the authors did not find a statistically significant relationship between OPTEMPO and part charges. This is potentially due to the OPTEMPO data being erroneously entered into the MIMMS database.

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V. MODEL SPECIFICATION

The following section lists the explanatory variables' likely effects on consumable and SECREP part charges.

Some variables have positive effects on part charges, while others have negative effects. Additionally, some variables have indirect effects on part charges by their effect on other explanatory variables. Figure 5 depicts the predicted relationships between the explanatory variables and the dependent variable.

- **Inventory:** positive effect on part charges. Each time a MARFOR fields a new TAMCN, it must account for the subsequent part charges of the TAMCNs. The only exception to this is TAMCNs under warranty or under a HQMC maintenance contract.
- **Average TAMCN cost:** positive effect on part charges. Since replacing parts is like remanufacturing, there should be a strong relationship between the cost of a TAMCN and the cost of its replacement parts.
- **Tracked vehicle indicator:** positive effect on part charges, relative to TAMCNs not "tracked." Tracked vehicles are maintenance intensive vehicles and should incur significantly more part charges than other TAMCNs.
- **MDBM:** negative effect on part charges. The longer a vehicle stays out of the maintenance cycle, the less money spent on part repair and replacement. The Marine Corps requires units to induct broken equipment into the maintenance cycle (MCO P4790.2C). At times, mechanics may classify vehicles in "short funds" status, meaning there is no money to order repair parts; however, this status is rarely seen in maintenance reports, and its effect on part charges is negligible.
- **Average IOC year:** negative effect on part charges. A larger IOC year signifies a newer TAMCN. For example, TAMCNs with IOCs of 2003 and 2006 are five and two years-old, respectively, in 2008. IOC year is used as a rough proxy for aging.[14]
- **Alpha, Bravo, Charlie, and Delta group indicators:** unknown effect on part charges, relative to Echo TAMCNs. If the Alpha indicator's coefficient is .2, then Alpha TAMCNs increase part charges by 20% more than Echo TAMCNs.

[14] There is generally a relationship between IOC year and aging due to technological enhancements. Newer equipment tends to be more reliable than older equipment. Therefore, newer equipment requires less maintenance and ages slower than older equipment.

- **SECREP indicator:** Effect on parts charges of SECREPs relative to consumables. SECREPs are typically more complex than consumables; thus, the SECREP indicator is expected to be positive, but the authors are going to wait to conclude on this matter until running empirical analysis.
- **MARFORPAC and MARFORCOM indicators:** unknown effect on parts charges, relative to TAMCNs in MARFORRES. On one hand, non-reserve units train more frequently, increasing part charges. On the other hand, there is more time for preventive maintenance in non-reserve units, decreasing part charges.
- **Tracks indicator:** unknown effect on part charges, relative to TAMCNs that are not tracks. Tracks are part intensive, increasing consumables and SECREP part charges.
- **APC indicator:** unknown effect on part charges, relative to TAMCNs that are not APCs. APCs are heavier than non-armored TAMCNs; therefore, may have higher part charges. However, it is not possible to be certain of the effect until empirical analysis is conducted.

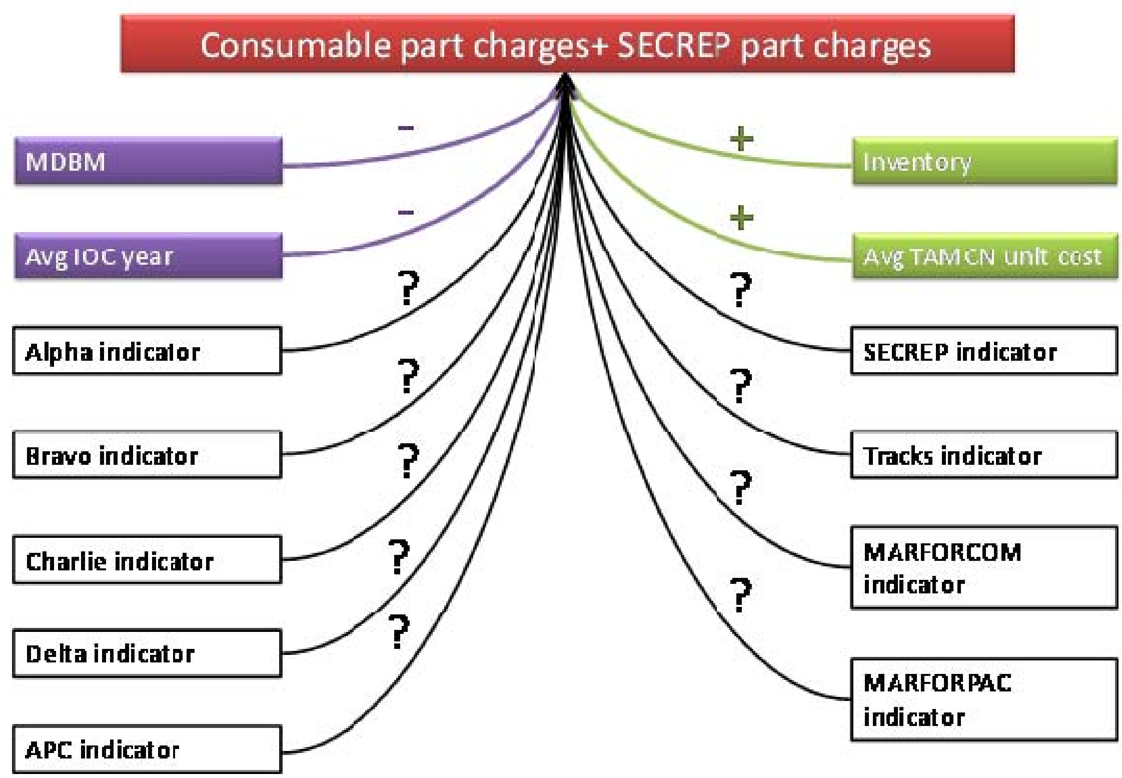

Figure 5. Model Specification

VI. RESULTS

This chapter contains three sections of data analysis: descriptive statistics, a policy response, and an AR forecasting. The descriptive statistics section discusses consumable and SECREPS part charges (i.e., part charges). The policy response section includes the results obtained when part charges are regressed on the explanatory variables. This model analyzes each explanatory variable's effect on part charges, holding all other explanatory variables constant. Finally, the prediction section provides an introductory AR forecasting model.

A. DESCRIPTIVE STATISTICS

1. Total Part Charges

Total Marine Corps parts costs increased by $30M from 2005–2008; however, this increase was not constant. Figure 6 shows large fluctuations in SECREP part costs, which led to overall part charge variability. For example, SECREP part charges doubled in 2006, leading total part charges to almost double. On the other hand, consumable part charges increased an average of ten percent each year.

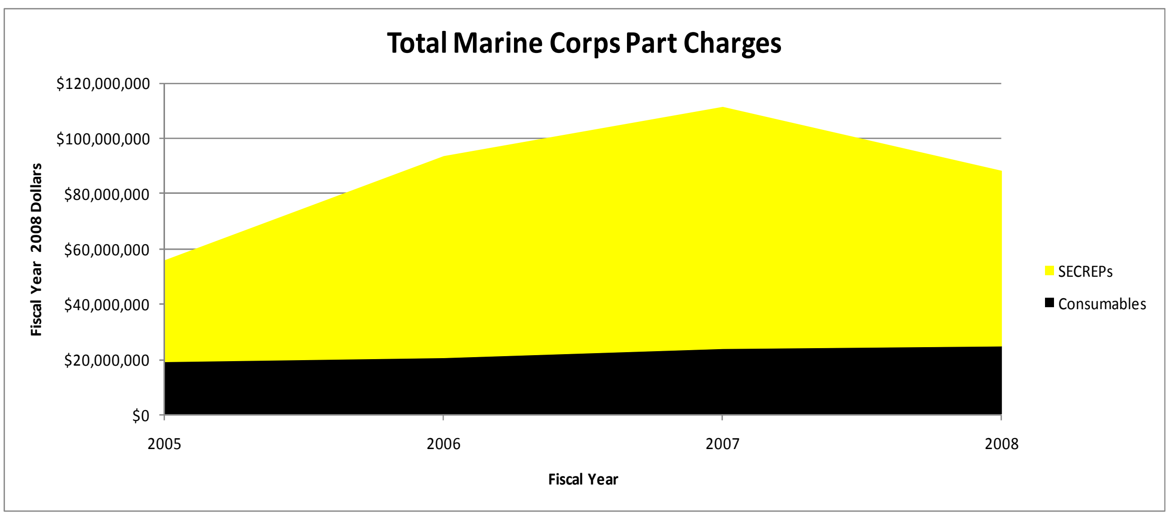

Figure 6. Total Marine Corps Part Charges

MARFORPAC's part charges increased by $16M from 2005–2008. Like total Marine Corps part charges, this increase was not constant. Figure 7 shows large fluctuations in SECREP part charges, which led to overall part charge variability. From 2006–2007, annual SECREP part charges increased by 50 and 40 percent, respectively. In 2008, SECREP part costs decreased by 20 percent. Annual consumable part charges were $13M on average, with a standard deviation of less than $1M.

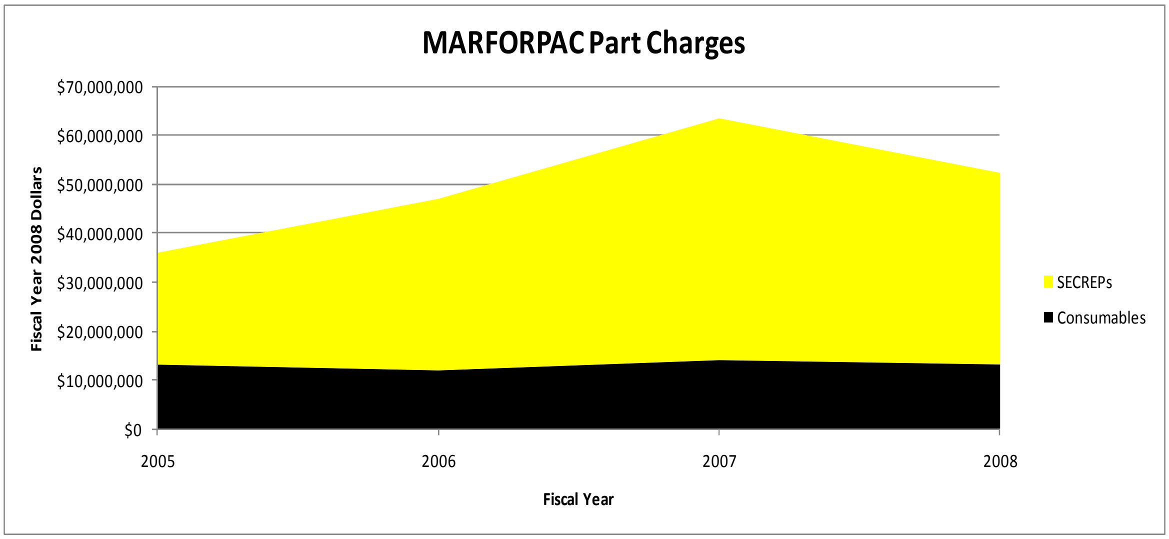

Figure 7. MARFORPAC Part Charges

MARFORCOM's part charges increased by $11M from 2005–2008. Like MARFORPAC, MARFORCOM's SECREP part charges changed significantly each year. SECREP part charges almost tripled in 2006, then decreased by 17 percent and 33 percent in 2007 and 2008, respectively. Additionally, consumable part charges doubled in 2006, then increased an average of 8 percent during the next two years. Figure 8 shows MARFORCOM's total part charges.

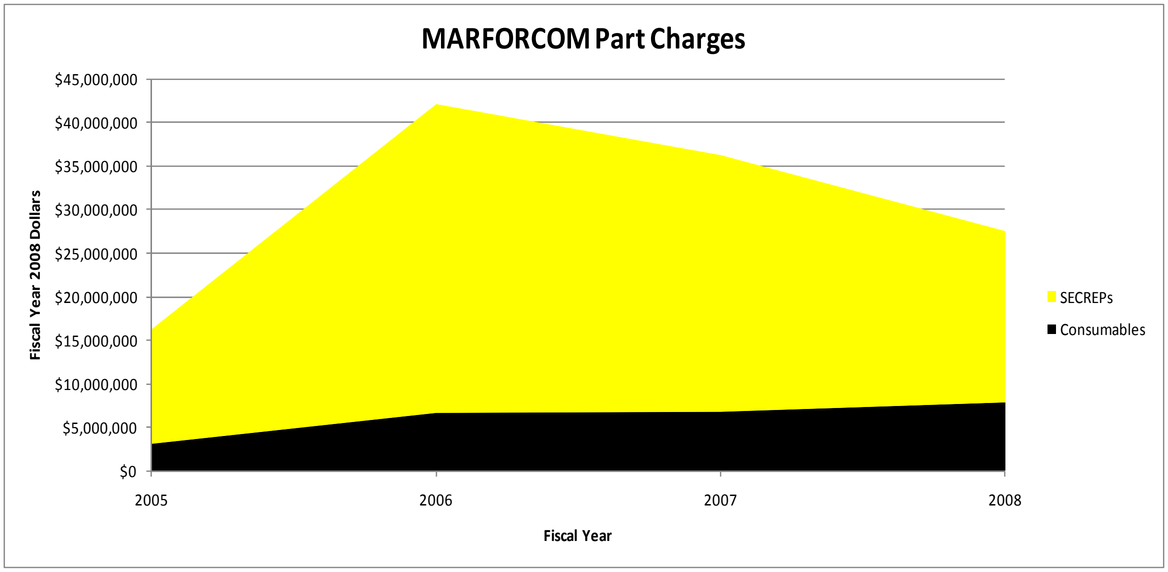

Figure 8. MARFORCOM Part Charges

MARFORRES' part charges increased by $8M from 2005–2008. MARFORRES' consumable and SECREP part charges varied the most out of the three MARFORs, in terms of percentage changes. SECREP part charges tripled in 2006 and 2007, and then decreased by half in 2008. Consumable part charges decreased by 33 percent in 2006, and then increased by 56 percent and 26 percent in 2007 and 2008, respectively. Figure 9 shows MARFORRES' total part charges.

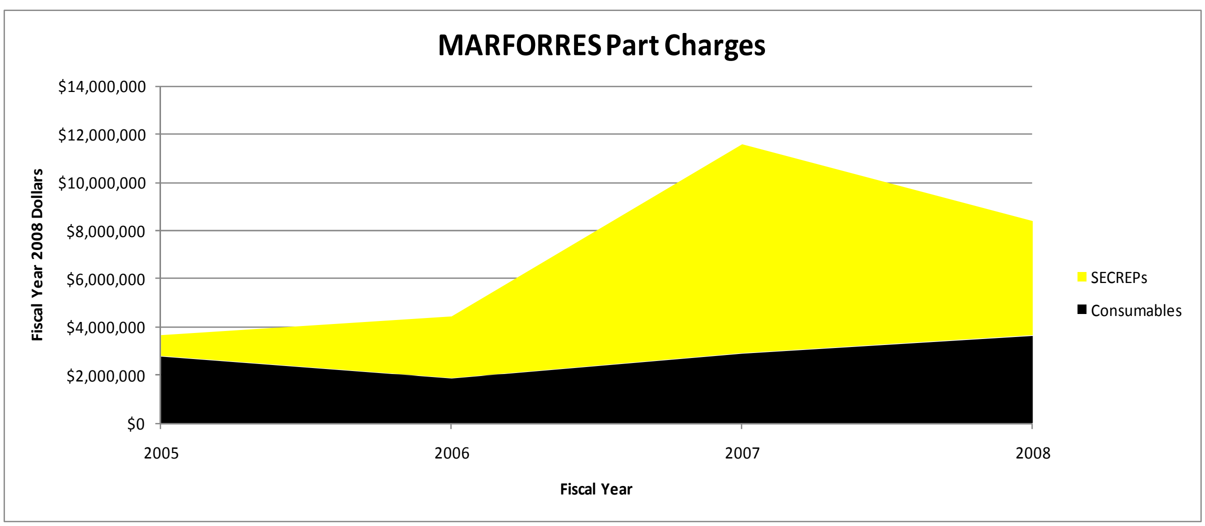

Figure 9. MARFORCOM Part Charges

2. The Most Expensive TAMCNs to Maintain

The Marine Corps directs approximately 70 percent of its part charge expenditures on 10 TAMCNs. These results are consistent with Kelly's 2009 study; however, the difference in make-up of the top 10 TAMCNs warrants another look. For example, Kelly's top two TAMCNs, the Tube-launched, Optical-sighted, Wire-guided TOW Launcher, and M2 Machine Gun, are 15th and 57th, respectively, using MERIT data. Figure 10 shows the part charges of the top 10 TAMCNs, and Table 6 shows the top 10 TAMCNs as a percentage of part charge expenditures.

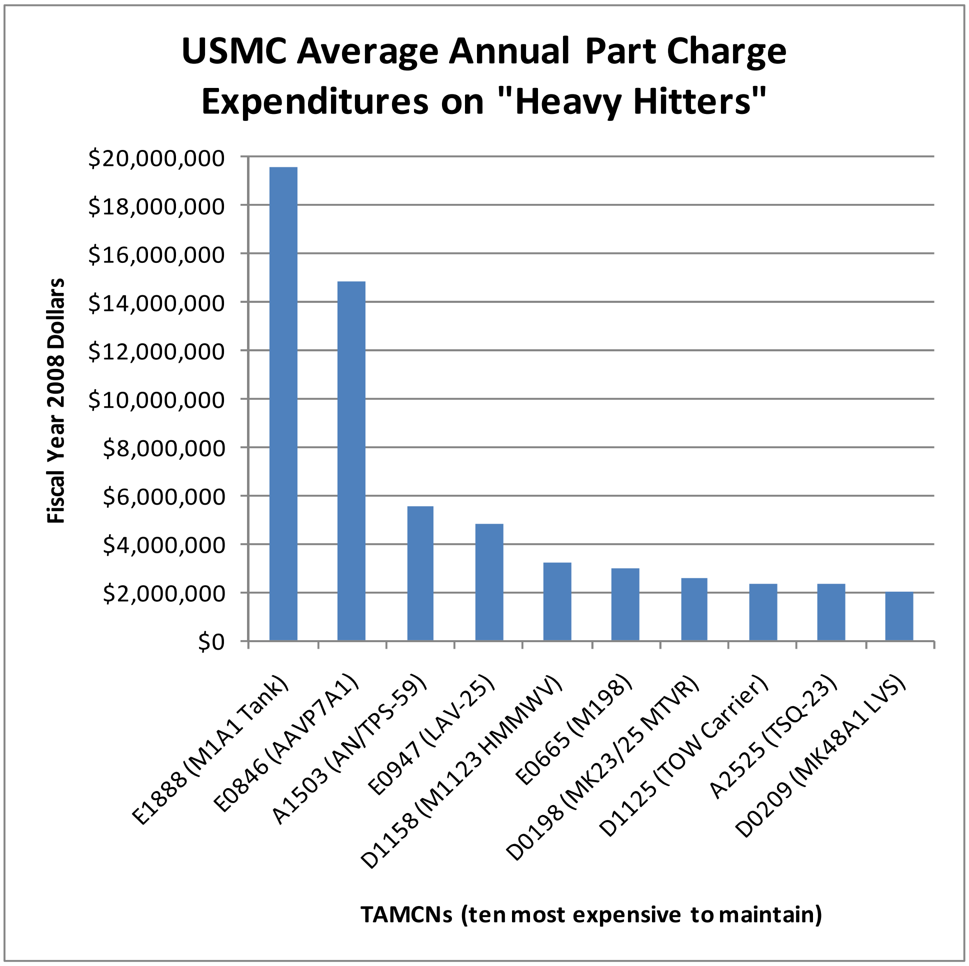

Figure 10. USMC Average Annual Part Charge Expenditures on "Heavy Hitters"

Marine Corps "Heavy Hitters" as a % of Total Part Charges		
TAMCN	**Average Annual Part Charges**	**Cumulative Percentage of Total Part Charges**
E1888 (M1A1 Tank)	$19,565,478	22.46%
E0846 (AAVP7A1)	$14,874,174	39.53%
A1503 (AN/TPS-59)	$5,565,556	45.92%
E0947 (LAV-25)	$4,814,162	51.44%
D1158 (M1123 HMMWV)	$3,270,184	55.20%
E0665 (M198)	$2,978,600	58.62%
D0198 (MK23/25 MTVR)	$2,573,718	61.57%
D1125 (TOW Carrier)	$2,359,299	64.28%
A2525 (TSQ-23)	$2,356,068	66.98%
D0209 (MK48A1 LVS)	$2,029,517	69.31%

Table 6. USMC “Heavy Hitters” as a Percentage of Total Part Charges

MARFORPAC’s top 10 TAMCNs differ from the Marine Corps as a whole by one TAMCN. MARFORPAC’s top 10 list includes the E1378 Tank Recovery Vehicles instead of the Logistics Vehicle System (LVS). MARFORPAC directs approximately 70 percent of its part charge expenditures on 10 TAMCNs. Figure 11 shows the part charges of the top 10 TAMCNs, and Table 7 shows the top 10 TAMCNs as a percentage of total part charge expenditures.

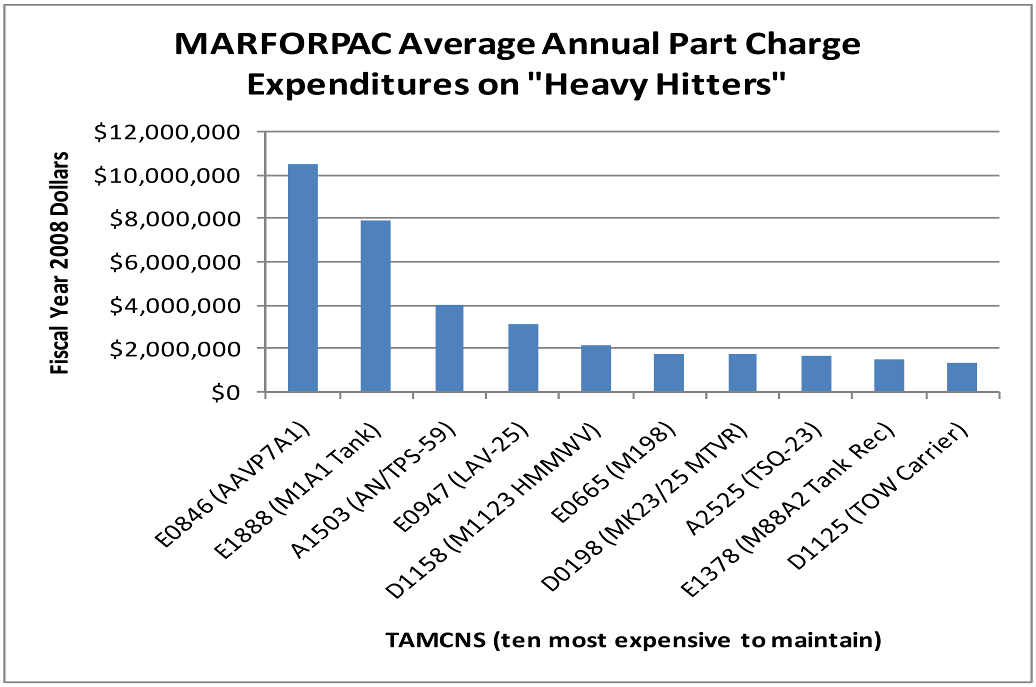

Figure 11. MARFORPAC Average Annual Part Charge Expenditures on "Heavy Hitters"

MARFORPAC "Heavy Hitters" as a % of Total Part Charges		
TAMCN	**Average Annual Part Charges**	**Cumulative Percentage of Total Part Charges**
E0846 (AAVP7A1)	$10,477,836	21.11%
E1888 (M1A1 Tank)	$7,862,454	36.95%
A1503 (AN/TPS-59)	$4,011,073	45.03%
E0947 (LAV-25)	$3,072,943	51.22%
D1158 (M1123 HMMWV)	$2,146,274	55.55%
E0665 (M198)	$1,765,677	59.10%
D0198 (MK23/25 MTVR)	$1,693,849	62.52%
A2525 (TSQ-23)	$1,629,310	65.80%
E1378 (M88A2 Tank Rec)	$1,463,880	68.75%
D1125 (TOW Carrier)	$1,321,497	71.41%

Table 7. MARFORPAC "Heavy Hitters" as a Percentage of Total Part Charges

MARFORCOM's top 10 TAMCNs differ from the Marine Corps as a whole by one TAMCN. MARFORCOM's top 10 list includes the E0942 Antitank Light Armored Vehicle instead of the A2525 Tactical Air Operations Module. MARFORCOM, like

MARFORPAC, directs approximately 70 percent of its part charges on 10 TAMCNs. Figure 12 shows the part charges of the top 10 TAMCNs, and Table 8 shows the top 10 TAMCNs as a percentage of total part charge expenditures.

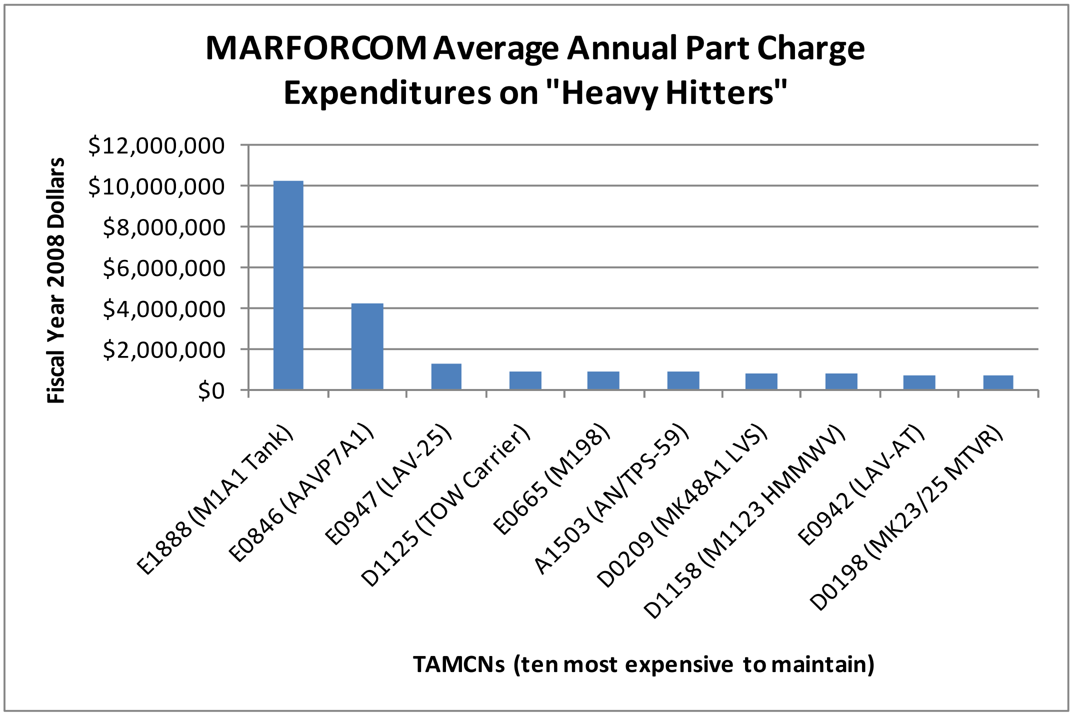

Figure 12. MARFORCOM Average Annual Part Charge Expenditures on “Heavy Hitters”

MARFORCOM "Heavy Hitters" as a % of Total Part Charges		
TAMCN	**Average Annual Part Charges**	**Cumulative Percentage of Total Part Charges**
E1888 (M1A1 Tank)	$10,196,269	33.45%
E0846 (AAVP7A1)	$4,252,966	47.41%
E0947 (LAV-25)	$1,267,505	51.57%
D1125 (TOW Carrier)	$939,494	54.65%
E0665 (M198)	$937,814	57.73%
A1503 (AN/TPS-59)	$937,783	60.80%
D0209 (MK48A1 LVS)	$805,193	63.45%
D1158 (M1123 HMMWV)	$751,244	65.91%
E0942 (LAV-AT)	$705,303	68.22%
D0198 (MK23/25 MTVR)	$673,180	70.43%

Table 8. MARFORCOM “Heavy Hitters” as a Percentage of Total Part Charges

MARFORRES' top 10 TAMCNs differ from the Marine Corps as a whole by three TAMCNs. MARFORRES' top 10 list includes the A0807 Satellite Terminal, A1500 Radar and E0935 TOW Launcher. Its top 10 list does not include the D0209 LVS, D1125 TOW HMMWV and E0848 Amphibious Assault Vehicle. Unlike the other MARFORs and the Marine Corps as a whole, MARFORES directs approximately 63 percent of its part charge expenditures on 10 TAMCNs. Figure 13 shows the part charges of the top 10 TAMCNs, and Table 9 shows the top 10 TAMCNs as a percentage of total part charge expenditures.

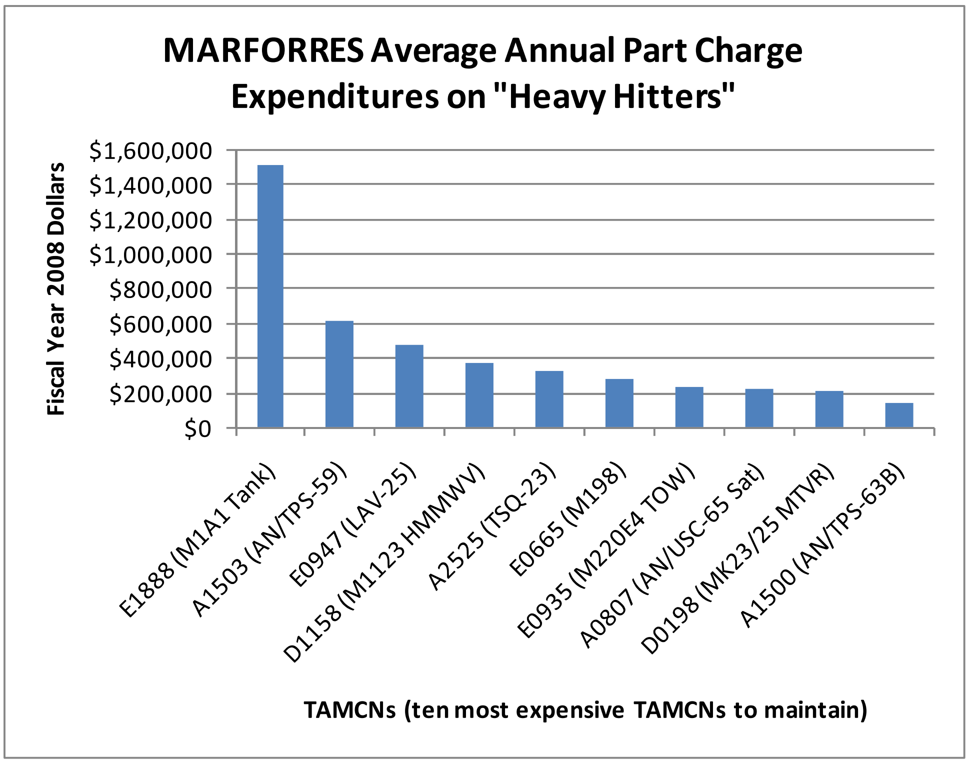

Figure 13. MARFORCOM Average Annual Part Charge Expenditures on "Heavy Hitters"

MARFORRES "Heavy Hitters" as a % of Total Part Charges		
TAMCN	**Average Annual Part Charges**	**Cumulative Percentage of Total Part Charges**
E1888 (M1A1 Tank)	$1,506,755	21.49%
A1503 (AN/TPS-59)	$616,700	30.29%
E0947 (LAV-25)	$473,714	37.04%
D1158 (M1123 HMMWV)	$372,666	42.36%
A2525 (TSQ-23)	$325,497	47.00%
E0665 (M198)	$275,109	50.92%
E0935 (M220E4 TOW)	$236,436	54.30%
A0807 (AN/USC-65 Sat)	$225,000	57.51%
D0198 (MK23/25 MTVR)	$206,689	60.45%
A1500 (AN/TPS-63B)	$146,286	62.54%

Table 9. MARFORRES "Heavy Hitters" as a Percentage of Total Part Charges.

B. INFERENTIAL STATISTICS

1. Policy Response Model

The standard test for a model's utility is to examine the actual data vs. the predicted data. A perfect fit exists when all data points fall on the regression line. Since our regression line did not produce a perfect fit, 95 percent confidence bands were included for an individual prediction, shown in Figure 14. The vast majority of the data fell between the confidence bands. The data that fell outside the confidence band are known as outliers. A preliminary analysis revealed that data errors or low inventory quantities are likely the cause for the outliers; however, a more in-depth analysis is needed and is beyond the scope of this thesis.

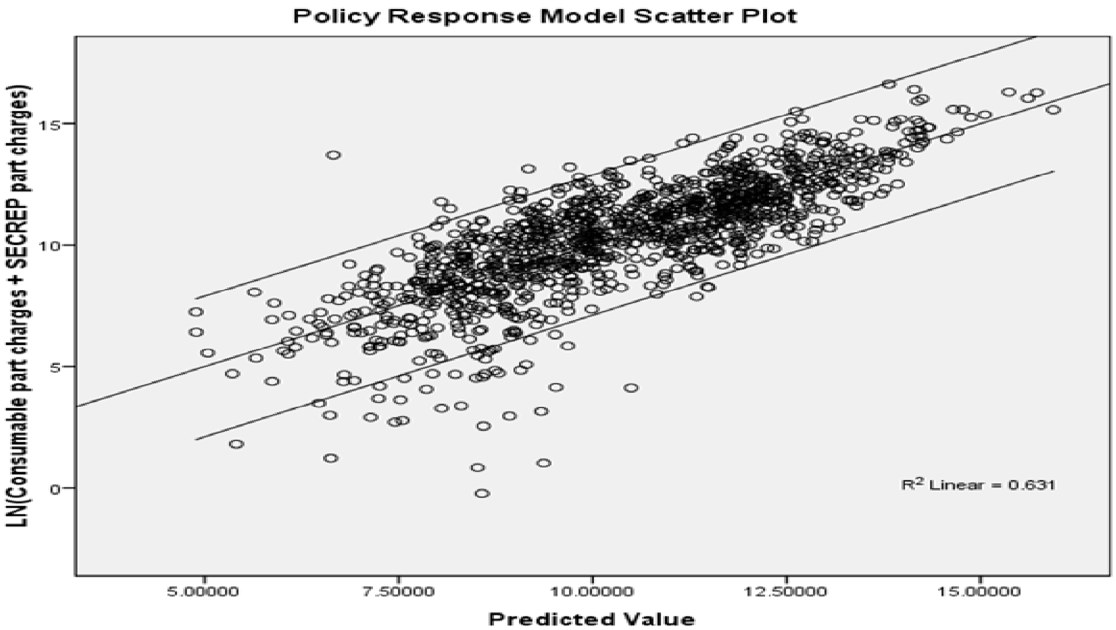

Figure 14. Policy Response Model Scatter Plot

This policy response model is best suited to understand an explanatory variable's effect on part charges, holding all other variables in the model constant. One can use this policy response model as a tool for predicting the change in one explanatory variable, holding other explanatory variables constant. The results in Table 10 provide the following cost estimating relationships:

Policy Response Model					
		95% Confidence Interval			
Explanatory Variable	**Coefficient**	**Lower bound**	**Upper bound**	**Std Error**	**t_statistic**
Constant	100.852	80.059	121.645	10.609	9.507
LN(Inventory)	0.826	0.754	0.899	0.037	22.335
LN(Mean days between maintenance)	-0.525	-0.696	-0.353	0.087	-6.002
LN(Average TAMCN cost)	0.605	0.532	0.678	0.037	16.292
Average IOC year	-0.050	-0.061	-0.040	0.005	-9.339
SECREP*	1.828	1.641	2.015	0.095	19.162
Armored Personnel Carrier*	0.474	0.120	0.828	0.181	2.626
Track TAMCNs*	0.810	0.356	1.265	0.232	3.495
Alpha TAMCNs*	0.615	0.342	0.887	0.139	4.420
Bravo TAMCNs*	0.382	0.126	0.638	0.131	2.921
Charlie TAMCNs*	-3.037	-4.171	-1.903	0.578	-5.251
Delta TAMCNs*	0.383	0.105	0.661	0.142	2.700
MARFORCOM TAMCNs*	0.242	0.030	0.454	0.108	2.242
MARFORPAC TAMCNs*	0.532	0.315	0.750	0.111	4.803
Dependent variable: LN (consumable part charges + SECREP part charges)					
R^2 = 0.631; N = 1253					
*Indicator/binary/dummy variable.					

Table 10. Policy Response Model

- **LN (inventory).** A 1 percent increase in inventory results in a .83 percent increase in part charges.
- **LN (mean days between maintenance).** A 1 percent increase in mean days between maintenance results in a .53 percent decrease in part charges.
- **LN (average TAMCN cost).** A 1 percent increase in average TAMCN cost results in a .61 percent increase in part charges.
- **Average IOC year.** A 1-year increase in a TAMCN's average IOC year results in a 5 percent decrease in part charges.
- **SECREP indicator.** TAMCNs with SECREP part charges incur 183 percent more part charges than TAMCNs with only consumable part charges.
- **APC indicator.** TAMCNs classified as APCs incur 47 percent more part charges than all other TAMCNs.
- **Tracks indicator.** TAMCNs classified as Tracks incur 81 percent more part charges than all other TAMCNs.

- **Alpha TAMCN indicator.** Alpha TAMCNs incur 62 percent more part charges, using Echo TAMCNs as the reference variable.
- **Bravo TAMCN indicator.** Bravo TAMCNs incur 38 percent more part charges, using Echo TAMCNs as the reference variable.
- **Charlie TAMCN indicator.** Charlie TAMCNs incur 300 percent less part charges, using Echo TAMCNs as the reference variable.
- **Delta TAMCN indicator.** Delta TAMCNs incur 38 percent more part charges, using Echo TAMCNs as the reference variable.
- **MARFORCOM indicator.** TAMCNs in MARFORCOM incur 24 percent more part charges, using MARFORRES as the reference variable.
- **MARFORPAC indicator.** TAMCNs in MARFORPAC incur 53 percent more part charges, using MARFORRES as the reference variable.

2. AR Forecasting Model

This study's primary goal was to create a policy response model; however, this study also developed an AR forecasting model. Table 11 summarizes the AR forecasting regression results. It shows modestly different explanatory variable coefficients, with a resulting larger R^2, which means that the AR forecasting model explains more of the variation in part charges than the policy response model. Table 11 also includes $\hat{\rho}$ (rho-hat), which takes into account the serial correlation of the residual at time t and time t-1.

AR Forecasting Model					
		95% Confidence Interval			
Parameter	**Estimate**	**Lower bound**	**Upper bound**	**Std Error**	**t_statistic**
Constant	103.785	76.575	130.995	13.834	7.502
LN(Inventory)	0.824	0.731	0.916	0.047	17.536
LN(Mean days between maintenance)	-0.370	-0.541	-0.199	0.087	-4.239
LN(Average TAMCN cost)	0.608	0.517	0.700	0.047	13.072
Average IOC year	-0.052	-0.066	-0.038	0.007	-7.440
SECREP*	1.786	1.587	1.985	0.101	17.629
Armored Personnel Carrier*	0.595	0.127	1.064	0.238	2.499
Track TAMCNs*	0.839	0.231	1.447	0.309	2.716
Alpha TAMCNs*	0.613	0.257	0.968	0.181	3.393
Bravo TAMCNs*	0.385	0.047	0.722	0.172	2.240
Charlie TAMCNs*	-2.973	-4.376	-1.571	0.714	-4.167
Delta TAMCNs*	0.449	0.082	0.816	0.187	2.407
MARFORCOM TAMCNs*	0.241	-0.036	0.518	0.141	1.711
MARFORPAC TAMCNs*	0.531	0.247	0.816	0.145	3.677
Dependent variable: LN (cosumable part charges + SECREP part charges)					
R^2 = 0.687; N = 877; rho-hat = 0.402; standard error of rho-hat = 0.035					
*Indicator/binary/dummy variable.					

Table 11. AR Forecasting Model

Although the AR model produces a higher R^2, Figure 15 shows numerous data points that fall outside the 95 percent confidence bands for the individual forecast. While this AR model is better for predicting total part charges than the policy response model, it cannot be used to analyze explanatory variables.

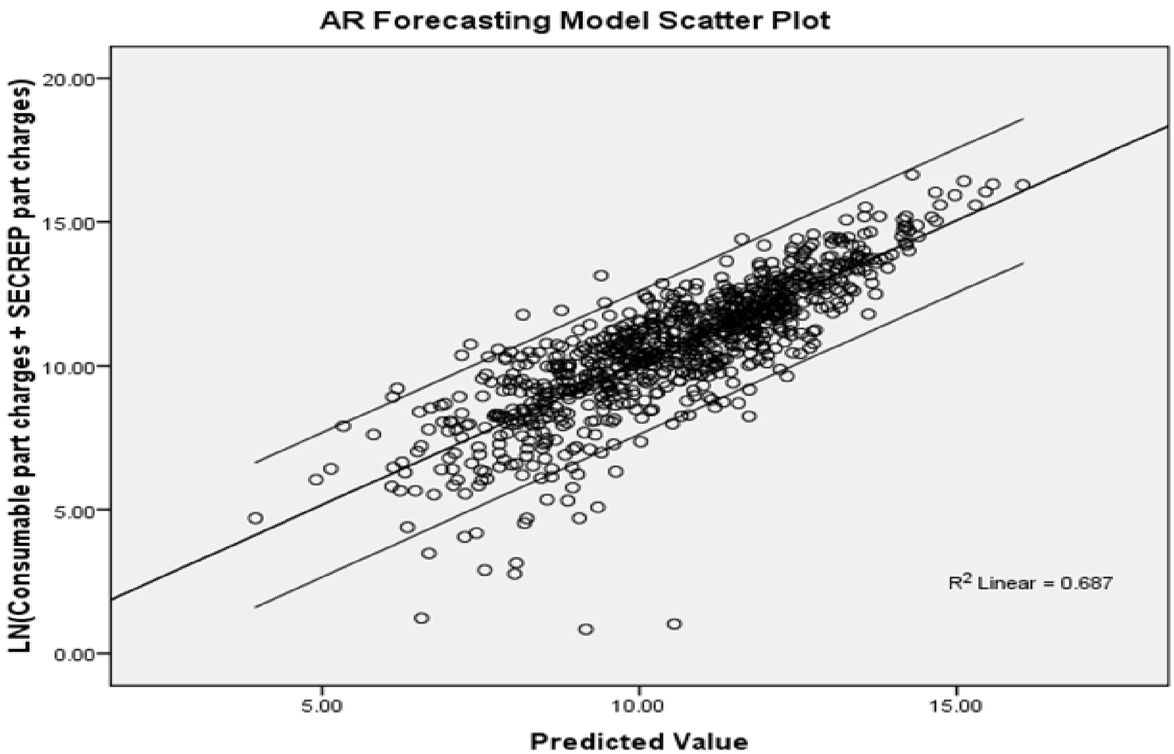

Figure 15. AR Forecasting Model Scatter Plot

The conclusion of the data analysis section includes a prediction of part charges from 2009 through 2010, as shown in Table 12. Again, factors outside the model and randomness can result in a good policy response model and a lackluster forecasting model. The model takes into account part charge decreases in FY 2008, and predicts a reduction in FY 2009 part charges. The model predicts another decrease in part charges for 2010, except in MARFORRES.

Forecasted Part Charges in MERIT			
	2008	2009	2010
MARFOR	Actual	Predicted	Predicted
MARFORCOM	$27,463,603	$32,907,600	$29,436,286
MARFORPAC	$52,238,309	$70,300,780	$66,413,076
MARFORRES	$8,385,431	$11,374,899	$11,771,438

Table 12. Forecasted Part Charges in MERIT

VII. CONCLUSIONS AND RECOMMENDATIONS

At the conclusion of this thesis, a policy response model as an initial analysis accurately reflects the capabilities and limitations of this thesis. The goal was to produce a performance-cost model that would provide HQMC I&L with forecasted part charges (by MARFOR) for comparison with the MARFORs' annual budget submissions. The authors attempted to produce this type of model, but the underlying requirement is accurate and reliable data, which cannot be emphasized enough. Cost estimating relationships are only as valid as their underlying data. This study highlights the need to capture both part charges and the values of potential explanatory variables properly. The following section lists conclusions and recommendations for future action:

- **The need for consistency between MERIT, VAMOSC, and budget submissions.** MERIT, VAMOSC, and the annual budget submission each has unique accounting rules. Consequently, historical aggregate part charges differ significantly, depending on the source. Furthermore, when this study deconstructed the parts charges into individual TAMCNs, MARFORs, SECREPs, and consumables, the discrepancies were quite large. MERIT and VAMOSC should align their data for data consistency. It is ultimately VAMOSC data that OSD looks at for budget submissions.
- **Planners should pull OPTEMPO data from operators.** When an artillery section chief inputs rounds-fired into his reports, planners should be able to go to a central database and access his information. Operators, not maintenance personnel, currently record reliable OPTEMPO data. For example, a Motor Transport Dispatcher must update a "miles driven" log every time a vehicle leaves the motor pool. The Motor Transport Operations Chief regularly inspects this log, and then forwards it to his higher command. Artillery chiefs, tanks chiefs, and other operators all place great importance on recording accurate OPTEMPO data. On the other hand, using-unit maintenance personnel are concerned about repairing equipment, and do not have any incentives to record proper meter reading when filling out EROs. In conclusion, this study did not find a significant relationship between OPTEMPO and part charges; however, using reliable OPTEMPO is the only way to way to validate OTEMPO's effect on part charges.
- **Conduct follow on studies of deployed units and MARFORSOC.** Deployed units experience both higher OPTEMPO and more austere environments. Consequently, different cost estimating relationships likely exist. Additionally, deployed units might spend the bulk of their

maintenance funds on different TAMCNs than they do when in garrison. For example, the Mine Resistant Ambush Protected vehicle, which is prevalent in Iraq, did not make the top 10 list in any of the MARFORs. MARFORSOC is another unit that likely spends maintenance funds differently than the regular MARFORs, because it has a different mission. MARFORSOC probably spends more maintenance funds on communication equipment and light vehicles than it does on heavy armor. This study estimates that planners have sufficient data to begin MARFORSOC part charge analysis by the end of 2010.

- **Repair the raw MIMMS and SASSY master data repository caused by the ATLASS II data transfer.** Finding accurate reliable data was difficult during the data collection phase. The authors looked into Raw MIMMS and SASSY data for the years 2002–2008 and were informed that data from the years 2002–2004 was inconsistent due to MARFORCOM was using ATLASS II, while all other MARFORs were using ATLASS I. When the data was transferred from ATLASS II to MIMMS/SASSY, the computer system entered “extended price” (quantity times unit price) in the “unit price” field, which resulted in a double counting error. If this data could be scrubbed and fixed, an additional three years of historical data would be applied to the database.

- **SECREP data in MERIT should include MRP credits and payments to LIS contractors.** Finding accurate SECREP data is an essential piece to capturing the true part charges associated with intermediate level maintenance. The authors found that MERIT provided the most accurate SECREP part charge data. When the IMA fixes a SECREP, this data is captured under “repair costs” in the total support cost tab (MARCORLOGCOM, 2009). When the RIP procures a SECREP via the MRP process and keypunches a ZBR (buy transaction), this data is captured under “SECREP Procurement” (MARCORLOGCOM, 2009) in the total support cost tab. The MRP credits transferred or reversed from the source of supply to the RIP is not captured under the SECREP procurement section of MERIT. This is a problem because the full purchase price of the SECREP is accounted for and not the exchange price, which is the actual cost. When the RIP releases an unserviceable SECREP to the LIS contractors for repair via a ZBE (release) transaction, the full unit price of the SECREP being transferred is captured under SECREP procurement in MERIT’s Total Support Cost tab (MARCORLOGCOM, 2009). The LIS contractors are paid using a MIPR and this data is stored in the SABRS system. This MIPR transaction is not recorded in MERIT. Instead of accounting for the ZBE transaction, one needs to look into SABRS to account for the actual cost of services performed by the contractor. If this data could be captured under SECREP procurement in the total support cost tab, the total cost of SECREPS is captured.

- **Create a TAMCN master database.** Having the following variables readily available and in one location increases the accuracy and credibility of future studies. Instead of creating a whole new database, one should look into augmenting this information with either MERIT or the SOE website. The following variables should be included.

  - **IOC Year:** This is an important variable to help determine the age of a TAMCN and when it was introduced into the Marine Corps inventory system. TFSMS was the source for IOC year. The authors found that this data had gaps and was incomplete. For example, while all TAMCNs have an IOC year, TFSMS did not list an IOC year for some TAMCNS. It is recommend that all serviceable TAMCNS have their IOC year input.

  - **Average Age:** This data requires a fielding schedule for every TAMCN variant and needs to be continuously updated for any changes. There needs to be one standard equation for calculating average age. The benefits to having average data is that one can determine the average age of the fleet and project the amount of funding required for overhaul and part charges with the assumption that as equipment ages, it is most likely that more is spent on part charges.

  - **TAMCN procurement cost:** Having the TAMCN unit cost by variant is significant in determining the average unit cost of the TAMCN, but is not currently available in a single database. This data can be used in regression analysis to determine if a TAMCN's procurement costs affects future part charge expenditures. The higher the TAMCN's procurement cost, the more likely spending is increased on SECREPS and consumable parts.

  - **OPTEMPO by TAMCN:** An accurate estimate of OPTEMPO could be a strong indicator of usage, and in turn, part charges. This variable was not used due to inaccuracies of MIMMS OPTEMPO data. The method for capturing this data needs to be improved before it can be applied to this master database.

  - **Inventory by MEF:** Inventory levels by MEF are needed to determine the size of the MEF. Having inventory levels broken down by TAMCN and by year provides a picture as to the growth of a MEF. This is with the assumption that more TAMCNs lead to higher part charge expenditures.

- Planners should further analyze the top 10 TAMCNs that consume the most part charges using the techniques applied in this study. The top 10 and 20 TAMCNs account for approximately 70 percent and 80 percent of part charges, respectively, so planners should spend time developing cost

estimating relationships for these TAMCNs. Planners might use cost factors to estimate the aggregate part charges of the remaining 208 TAMCNs.

APPENDIX. LISTING OF TAMCNS

Table of Marine Corps Readiness Evaluation System (MARES) Equipment

TAMCN	FA CODE	WSC	Nomenclature	MEE
A0013	13	8S	Theater Battle Management Core System AN/TYY-2	AN/TYY-2
A0020	13	AB	Direct Air Support Central, Airborne System (DASC, AS)	
A0021	13	6A	Communications Data Link System, TYQ-101A	TYQ-101A
A0025	13	5T	Communications Platform, Air Defense (ADCP)	AN/MSQ-124
A0060	19	AE	Joint Services Workstation, AN/TSQ-220 (V)	AN/TSQ-220
A0067	9	DL	Radio Set, AN/MRC-148	
A0068	10	IY	Radio Set, Tactical Long Haul Digital Link-11, AN/GRC-256	AN/GRC-256
A0069	9	0G	Radio Set, Vehicle, Dual VAA, AN/VRC-111	
A0075	9	VM	AN/VRC-104	
A0116	16	OJ	I PADS	
A0122	16	9Y	PHOENIX	PHOENIX
A0124	6	2Y	Remote Subscriber Access Module (RSAM) AN/TTC-63	
A0125	6	1Y	Deployable End Office Suite	
A0126	9	VM	Multiband Frequency, Vehicle Mounted, Radio System AN/VRC-103 (V)2	
A0132	6	UY	Deployable Integrated Transport Suite (DITS)	
A0138	19	AE	Tactical Exploitation Group - Remote Workstation	TEG-RWS
A0139	10	C9	Radio Set, AN/TRC-209	
A0149	9	E3	Antenna COMM TRL Mounted AS-4429D	AS-4429D
A0153	9	--	Radio Set, AN/MRC-142C	
A0170	19	--	AN/TSQ 226 (V)3 Trojan Spirit	AN/TSQ 226
A0172	7	HZ	DDS-R/M PWR Module (PM)	
A0173	7	HZ	DDS-R/M COMM Security Module (CSM)	
A0174	7	HZ	DDS-R/M LAN Service Module (LSM)	
A0175	7	HZ	DDS-R/M Configuration Module (CM) Laptop IBM	
A0176	7	HZ	DDS-R/M LAN Extension Module ON-704/TYC	
A0177	7	HZ	DDS-R/M APP SVR Module (ASM) AN/TYQ-147	
A0180	13	8A	AN/TYQ-145 Beyond Line of Sight Gateway	
A0182	19	--	Tactical One Roof	
A0197	7	6J	DDS-R/M Data Storage Module (DSM)	DSM
A0234	7	IT	SWAN D (V)1	SWAN D (V)1
A0241	7	3G	SWAN D (V)2	SWAN D (V)2
A0242	7	3J	Satellite Communication Subsystem	SCS
A0243	7	3N	SWAN D Network Package	SWAN D
A0244	7	3O	Network Management System	NMS
A0254	10	OL	Combat Ops Center, Set III - AN/TSQ-239(V)3	
A0255	10	OM	Combat Ops Center, Set IV - AN/TSQ-239(V)4	
A0273	9	6K	Radio Set, Vehicular, DVA, AN/VRC-110	
A0282	7	3Y	Team Portable Collection System Multi-Platform Capable	TPCSMPC
A0425	7	8N	AN/GSC-68(V)1/Mounted Digital Automated Communications Terminal (MDACT)	
A0499	7	Y3	Digital Technical Control (DTC), Facility, AN/TSQ-227	
A0806	5	B9	Lightweight Multiband Satellite Terminal (LMST) HUB AN/USC-65(V)1	
A0807	5	B9	Lightweight Multiband Satellite Terminal (LMST) Mini-HUB AN/USC-65(V)2	
A0814	5	BH	Communications Terminal, AN/TSC-93C (V)1	
A0873	13	U3	Server, INTEL OPS (IOS_OPS)	

TAMCN	FA CODE	WSC	Nomenclature	MEE
A0880	14	EN	AN/UPX-37 Interrogator Set	AN/UPX-37
A0882	10	36	Joint Tactical Information Distribution System (JTIDS) AN/URC107(V)10	AN/URC-107(V)10
A0886	7	85	JT Enhanced Core COMM SYS (JECCS)	
A0921	19	G4	AN/TSQ 226 (V)1 Trojan Spirit Lite	AN/TSQ 226 (V)1
A0932	19	ID	IOW	
A0940	7	4X	PFED	
A0966	19	5J	Mobile EW Support System, AN/MLQ-36	
A1225	10	BN	AN/TSQ-158A/EPLRS Network Manager (ENM)	
A1260	5	4A	GPSS-DAGR	GPSS-DAGR
A1380	5	8H	Antenna, Lightweight High Gain X-Band (LHGXA), AS-4429	
A1440	43	BP	Radar Set, Fire Finder, AN/TPQ-36/AN/TPQ-46	TPQ-46
A1500	14	GS	Radar Set, AN/TPS-63B	
A1503	14	BQ	Radar Set, LW3D, AN/TPS-59(V)3	AN/TPS-59(V)3
A1520	19	AE	Radar System Attack Target JT, AN/TSQ-179(V)1, JSWS/JSTARS CGS	AN/TSQ-179B JSTARS
A1818	10	56	Radio Set, AN/GRC-171B(V)4	
A1954	8	5D	Radio Terminal Set ,AN/MRC-142B	
A1955	8	SD	Radio Terminal Set, AN/MRC-142A	
A1957	9	4R	Radio Set, AN/MRC-145A	
A2042	10	8T	High Frequency Manpack Radio, AN/PRC-150	
A2044	10	E3	Radio Set, Manpack, PRC-148(V)1	
A2068	10	8T	AN/PRC-117F/Radio Set, Multiband, Falcon II	
A2070	10	2Z	Radio Set, Manpack, AN/PRC-119A	
A2075	9	2Z	Radio Set, Vehicular AN/VRC-89D	
A2076	9	2Z	Radio Set, Vehicular AN/VRC-90D	
A2077	9	2Z	Radio Set, Vehicular AN/VRC-91D	
A2078	9	2Z	Radio Set, Vehicular - AN/VRC92D	
A2079	10	2Z	Radio Set, Manpack, AN/PRC-119F	
A2152	10	Z4	AN/VSQ2C/Enhanced Position Location Reporting System (EPLRS)	
A2179	8	FW	Radio Terminal Digital, Troposcatter, AN/TRC-170	
A2390	13	8A	Sector Anti-Air Warfare FAC, AN/TYQ-87	
A2525	13	BY	Tactical Air Operations Module, (TAOM), AN/TYQ-23(V)4	AN/TSQ-23(V)4
A2533	7	HZ	Data Distribution System, AN/TSQ-228 (V)3	
A2534	7	6G	Data Distribution System, AN/TSQ-228 (V)2	AN/TSQ-228 (V)2
A2535	7	7U	Tactical (Gateway) Data NetworkAN/TSQ-222	
A2538	7	7U	AN/TSQ-228(V)1/Data Distribution System, Tactical Server (DDS)	
A2551	19	2J	Tactical Command System, AN/USC-55A	
A2555	13	51	AFATDS	
A2560	13	4X	Target Loc, Desig & Hand-Off Sys (TLDHS)(BLK II) - AN/PSQ19A	
A2628	19	7G	Tactical Control and Analysis Center, Transportable	TCAC TW
A2634	19	6P	Tactical Control and Analysis Center, (TCAC-RAWS)	
A3232	5	7K	Secure Mobile Anti-Jam Reliable Tactical Terminal (SMART-T), AN/TSC-154	AN/TSC-154

TAMCN	FA CODE	WSC	Nomenclature	MEE
A3252	19	IE	UAV System, Dragon Eye	
A3270	13	6A	Communications Interface System, AN/MRQ-12(V)3	AN/MRQ-12(V)3
A8018	97	HE	Interrogator Computer, TSEC/KIR-1C	
A8019	97	HK	Transponder Computer, TSEC/Kit-1C	
A8038	97	HL	Electronic Key Generator, TSEC/KG-40A/P	
A8072	97	6H	Remote Rekey Equipment	
A9001	97	8N	Computer Set, Digital (Blue Force Tracker)	
B0001	21	MU	Air Conditioner, MCS Horizontal, 60HZ, 9K BTU	
B0003	21	JB	AC, 1.5 Ton, 60HZ	
B0004	21	JC	AC, 1.5 Ton, 400HZ	
B0006	21	JE	AC, 3 Ton, 400HZ	
B0008	21	JH	AC, 5T, 60K	
B0012	21	2U	Environmental Control Unit (Air Conditioner) 18K BTU/HR, 400HZ	
B0014	21	IZ	Environmental Control Unit (Air Conditioner)	
B0018	21	53	Integrated Trailer ECU	
B0025	29	0Y	Hydroseeder, Trailer Mounted	
B0026	29	N1	Hydroseeder, Skid Mounted	
B0035	29	3T	Hardened Engineer Vehicle (BUFFALO)	
B0038	29	B1	All Terrain Crain (ATC) MAC-50	
B0039	29	1Z	Airfield Damage Repair (ADR) Kit-GBE Runway REP	
B0063	29	0D	624K TRAM	
B0074	21	4O	AC, .75 Ton	
B0114	24	MK	Boat, Bridge Erection, USCSBMK3	USCSBMK3
B0152	24	JT	Bridge, Medium Girder (MGB), Dry Gap	MGB2
B0155	24	2K	Bridge, Floating Ribbon, 70-Ton	FBR-70
B0160	29	3W	Assault Breacher Vehicle	ABV
B0392	29	JV	Container Handler, RT, KALMAR	
B0476	29	IG	Detecting Set, Mine, AN/PSS-14	PSS14
B0589	23	3Q	Excavator Combat, M9 ACE	M9 ACE
B0675	25	KF	Fuel Dispensing System, Tactical, Airfield, M1966	TAFDS
B0685	25	KG	Fuel System Amphibious Assault, M69HC	AAFS
B0730	20	KH	Generator Set, 3KW, 60HZ, Skid-Mtd MEP831A	
B0891	20	KK	Generator Set, Skid Mtd, 10KW/60HZ, TQG MEP803A	
B0921	20	KL	Generator Set, Skid Mtd, 10KW/400HZ, TQG MEP 813	
B0930	20	OZ	Generator Set, 60HZ, MMG 25	
B0953	20	7M	Generator Set, 30KW, 60 HZ, Skid Mtd, MEP-005A/805A/B	
B0971	20	7N	Generator Set, 400HZ, 60KW, 400HZ, Skid Mtd, TQG 815	
B0980	20	YY	Generator Set, 60HZ, MEP 513A	
B1016	20	KN	Generator Set, 60KW, 400HZ, Skid Mounted, MEP-816A	
B1021	20	KP	Generator Set, 60 KW, 60 Hz, Skid Mounted, MEP-006A/806B	
B1045	20	KM	Generator Set, 100KW, 60HZ, SKID-MTD, TQG-MEP-807A	
B1082	23	FU	Grader, Road, Motorized-130G	
B1135	25	KQ	Refueling System, Expedient, HELO-81A5013A0000	
B1315	29	J8	Mine Clearing Launcher, MK-154, MOD 0	MK-154
B1580	25	KU	Fuel Pump Module (SIXCON)	
B1785	23	LZ	Roller, Compactor, Vibratory, Self-Propelled-CS563D	

TAMCN	FA CODE	WSC	Nomenclature	MEE
B2085	25	MT	Storage, Tank, Module, Fuel (SIXCON)	
B2086	25	M3	Storage, Tank, Module, Water (SIXCON) MWT166	
B2127	33	8P	Sweeper, Rotary, Vehicle Mounting	
B2462	23	7E	Tractor, Medium, Full-Tracked D7G, Caterpillar	D7G
B2483	23	2	Loader, Backhoe (BHL)	
B2561	26	MC	Forklift, Extended Boom	
B2566	26	KV	Light Capacity, Rough Terrain Forklift	
B2567	23	Z2	Tractor, Rubber Tire, Articulated Steer, MP (TRAM)-644E	TRAM 644E
B2605	29	IH	Tactical Water Purification System (TWPS)	TWPS
C2278	98	--	Oxygen Mask	
C2282	99	7V	NBC Reconnaissance System (FOX) M93	FOX
C2286	98	--	Oxygen System, Portable	
C2288	98	--	Re-Breather Unit, Oxygen, Portable - Phaos, Oxcon	
C4185	98	1J	Breathing Apparatus, Underwater-MK25 MOD2	
C4549	98	IK	Device Propulsion, Diver	
C5649	98	IM	Parachute Personnel, Maneuverable (MMPS)	
C5901	98	4V	Raiding Craft, Cmbt, Rubber, Inflatable, (CRRC) F470 Full up	
D0001	30	SR	Truck Utility, Up-Armored HMMWV (UAH) M1114	
D0003	31	I1	Truck, Armored, 7 ton Cargo, AMK23	
D0004	31	Z1	Truck, Armored, 7 Ton Cargo w/ Winch, AMK25	
D0005	31	Y1	Truck, Armored, 7 Ton Ext L WHLB, AMK27	
D0006	31	X1	Truck, Armored, 7 Ton Ext L WHLB w/ Winch, AMK28	
D0007	31	X1	Truck, Armored, Dump, 7 Ton, AMK29	
D0008	31	F2	Truck, Armored, Dump, 7 Ton w/ Winch, AMK30	
D0009	31	U1	Truck, Tractor, 7T, w/o Winch - MK31	
D0013	31	F2	Tractor, MTVR, w/o Winch, Armored - AMK31	
D0015	31	F2	Truck, Armored, Wrecker, 7 Ton w/ Winch, AMK36	AMK36
D0022	29	IN	Truck, Utility, Expanded Capacity, Enhanced, 11,500 GVW, 4x4, M1152 (2-Door)	
D0025	29	IQ	MRAP JERRV, 4X4	
D0027	29	IR	MRAP JERRV, 6X6	
D0030	30	OQ	Truck, Utility, Expanded Capacity, Armored Carrier, M1151	
D0031	29	5A	Truck, Utility, Expanded Capacity, G2/GP Vehicle	
D0033	30	5G	Truck, Utility, Expanded Capacity, Enhanced, Armored, 2-Door	
D0034	29	5E	Truck, Utility, Expanded Capacity, CMD&CNTRL GP	
D0081	26	--	Trailer, General Purpose, 4 Ton, 4 Wheel, MK18A1	
D0198	31	F2	Truck, Cargo, 7 Ton, W/O Winch (MTVR) MK23/MK25	
D0209	32	QE	Power Unit, Front, 4x4, MK 48, Mod 0	MK48A1
D0215	32	RY	Semi-Trailer, Refueler, 5000 GAL-MK970A	MK970A
D0235	32	RZ	Semi-Trailer, 40-Ton Low-Bed, 12- Wheel, M870	M870A2
D0861	32	QE	Trailer, Cargo, Resupply F/HIMARS, MK38	
D0876	32	QE	Trailer, Powered, Container Hauler 4x4, MK14	
D0877	32	QE	Trailer, Powered, Wrecker/Recovery, 4x4-MK15A1 Mod 0	MK15A1 Mod 0
D0878	32	QE	Trailer, Powered, 5th Wheel 4x4, MK16, Mod 0	MK16
D0880	31	Q6	Trailer, Tank, Water, 400 Gal, M149A2	
D0881	32	QE	Trailer, Ribbon Bridge-MK18A1	MK18A1

TAMCN	FA CODE	WSC	Nomenclature	MEE
D1001	30	QP	Truck, Ambulance, 4 Litter, Armored, 1 ¼ Ton, HMMWV, M997	
D1002	30	QQ	Truck, Ambulance, 2 Litter, Soft Top, 1 ¼ Ton, HMMWV, M1035	
D1062	31	F2	Truck, Cargo, 7 Ton, XLWB, MK27/MK28	
D1063	43	F2	MTVR, MK37 (MK27 w/ crane)	
D1064	33	SG	Trk, Fire Fighting, Aircraft and Structure, A/S32P-19A	A/S32P-19A
D1073	31	F2	Truck, RTAA, Dump, 7 Ton w/Winch	
D1125	48	QR	Truck, Utility, TOW Carrier, HMMWV, M1045/M1046	TOW Carrier
D1158	30	SF	Truck, Utility, Cargo, Troop Carrier, HMMWV, M1123	
D1159	30	QS	Truck, Utility, Armored Carrier, W/SA, 2 ¼ Ton, HMMWV	
D1160	30	8V	Interim Fast Attack Vehicle (IFAV), 04751E	
D1213	31	F2	Truck Wrecker, MTVR, MK-36,	MK-36
E0006	43	4C	Illuminator, Infared (IZLID 1000P)	
E0020	47	4D	Scout Sniper Medium Range Night Sight	
E0055	48	76	Launcher, Tubular F/GM(TOW), M41A1 SABER	
E0149	40	UG	Bridge, Scissor for AVLB	
E0150	40	UJ	Launcher, Bridge, Armored Vehicle, M60A1	
E0180	43	UH	Circle, Aiming	
E0207	48	4D	Command Launch Unit, Javelin M98A1	M98A1
E0311	47	--	M14/Sniper Rifle, EMR	
E0330	48	UP	Sight, Thermal, AN/UAS-12C Hybrid	
E0665	43	U7	Howitzer, Medium, Towed 155MM, M198	M198
E0671	43	6F	Howitzer, Light Weight Medium, Towed, M777	M777
E0796	41	X2	Assault Amphibious Vehicle, Command/Communications, AAVC7A1	AAVC7A1
E0846	41	X3	Assault Amphibious Vehicle, Personnel, AAVP7A1	AAVP7A1
E0856	41	X4	Assault Amphibious Vehicle, Recovery, AAVR7A1	AAVR7A1
E0915	48	UA	Launcher, Assault Rocket, 83mm, MK153, Mod 0	
E0935	48	XR	Launcher, Tubular F/GM (TOW), M220E4	M220E4
E0942	42	VM	Light Armored Vehicle, Anti-Tank, LAV-AT	LAV-AT
E0946	42	VM	Light Armored Vehicle, Command/Control, LAV-C2	LAV-C2
E0947	42	VM	Light Armored Vehicle, 25mm, LAV-25	LAV-25
E0948	42	VM	Light Armored Vehicle, Logistics, LAV-L	LAV-L
E0949	42	VM	Light Armored Vehicle, Mortar, LAV-M	LAV-M
E0950	42	VM	Light Armored Vehicle, Maint/Recovery, LAV-R	LAV-R
E0980	45	VD	Machine Gun, Cal .50, Browning, HB Flexible - M2	
E0984	45	8X	Machine Gun, Cal .50	
E0989	45	58	Machine Gun, Medium, 7.62MM, Ground Version - M240B	
E0994	45	UB	Machine Gun, 40MM - MK19 MOD3	
E1030	48	TB	GLTD II Target Designator	
E1048	48	--	Vector 21	
E1065	46	V9	Mortar, 60MM, M224	
E1095	46	B3	Mortar, 81mm, M252	M252
E1145	43	8F	Velocity System, Muzzle (MVS)	
E1210	43	KD	Position Azimuth Determination System (PADS)	
E1378	40	XY	Recovery Vehicle, Heavy, Full-Tracked, M88A2	M88A2

TAMCN	FA CODE	WSC	Nomenclature	MEE
E1460	47	WC	Rifle, Sniper, 7.62MM, W/Equipment	
E1475	47	4J	Rifle, Scoped, Special Application, .50 CAL	
E1500	43	8Y	High Mobility Artillery Rocket System	HIMARS
E1839	49	G1	Advanced Man Portable Air Defense System	
E1888	40	UK	Tank, Combat, Full-Tracked, 120mm Gun, M1A1	M1A1
E1906	40	8B	Direct Support Electrical System Test Set (DSETS), AN/USM-615	
E1975	48	7C	Sight, Weapon, Thermal, Medium (MTWS)	
E1976	48	7C	Sight, Weapon, Thermal, Heavy ((HTWS)	

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